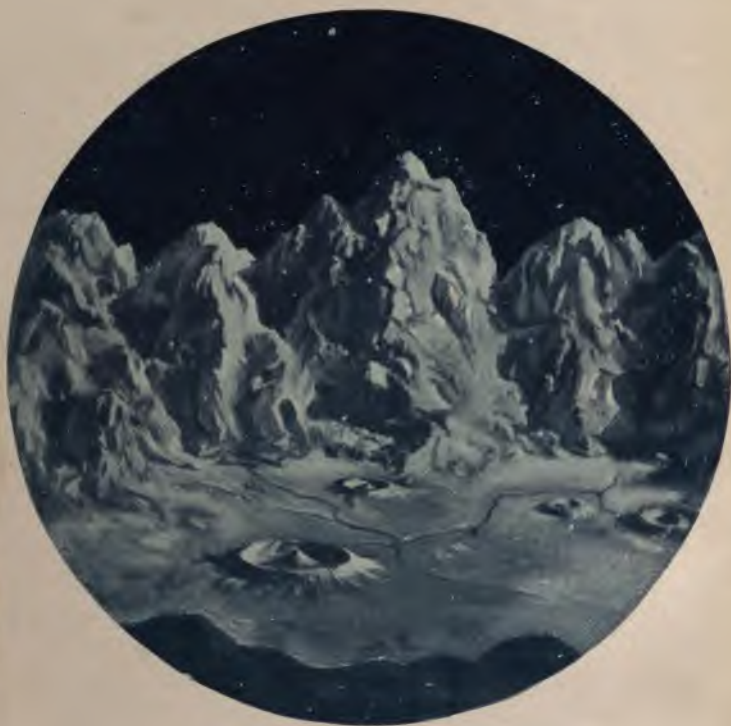

An Ideal Group of Lunar Mountains.

GIANT SUN

AND HIS FAMILY

BY

MARY PROCTOR

AUTHOR OF "STORIES OF STARLAND"

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PREFACE

It may be truly said that this little volume is the result of ten years' experience in lecturing on the subject "Giant Sun and His Family." During these ten years the author has had the opportunity to deliver her lectures on this theme before many schools and in connection with the evening lecture course conducted by the New York City Department of Education. Out of the interest displayed in these lectures has grown this volume, intended for children of the higher grammar grades. Of many valuable and instructive hints and suggestions received from friends and auditors the author has availed herself, and very greatly at their request has incorporated these lectures into book form, adding thereto an account of her actual experiences on the three occasions when she was fortunately able to observe the total eclipse of the sun.

To several astronomers who have kindly furnished her with valuable illustrations for the book, the author desires to make special acknowledgment.

If the book itself succeeds in making young readers desirous of pursuing still further the study of astronomy, the writer will feel greatly rewarded for her efforts.

New York,
January 1, 1906.

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CHAPTER I

THE SUN AS A STAR

"Giant Sun and Giant Strength are ugly qualities without beneficence. But the sun is the almoner of the Almighty, the delegated dispenser to us of light and warmth, as well as the center of attraction, and as such the immediate source of all our comforts, and indeed of the very possibility of our existence on earth."

— Sir John Herschel.

Strange as it may seem, the sun is a star, resembling the stars we see shining in the sky. Stranger still is the fact that, compared with other stars, "Giant Sun," as we call him, is only of medium size. We are nestled comparatively close to the sun-star, we people on earth, but we are separated from the nearest of all the other stars by a mighty abyss. This is why the sun appears to us to be the largest of all the stars.

If the sun were gradually to retreat from the earth to a distance equal to that which separates us from the nearest of the other stars, his light would grow so dim, so far as we are concerned, that he would be utterly shorn of his glory. In size, he would dwindle down to that of a moderately bright star. But even after he had "dwindled down," he would still be a greater giant than we could possibly imagine.

The Size of the Sun

The size of the sun, though relatively small when compared with that of the other stars, is enormous when compared with the size of the earth. If, for example, the sun

THE COMPARATIVE SIZE OF THE SUN AND THE EARTH.
The little dot at the right of the sun indicates the earth.

were represented by a globe 26 feet in diameter, the earth to be in proportion would have to be as small as a tennis ball. *The diameter of the sun is* 866,500 *miles, or* 109½ *times that of the earth.* "A traveler who could make the

circuit of the world in 80 days would need nearly 24 years for his journey around the sun."[1]

The Volume and Mass of the Sun

The volume of the sun exceeds that of the earth 1,300,000 *times;* so that if the sun could be divided into 1,300,000 parts, each part would equal the earth in size.

THE WASHINGTON MONUMENT.

Professor Howe, of Denver, in his book entitled "Descriptive Astronomy," gives an amusing illustration as to what would happen if the earth were to swell to the size of the sun, and if men were to increase in like proportion. At this rate, he says, an average man would be 625 feet tall; that is, he would be able to stand beside the Washington Monument (which is 555 feet high) and look over the top of it with ease.

The mass of the sun, or the quantity of matter that it

[1] C. A. Young, "The Sun," p. 39.

contains, exceeds that of the earth about 333,000 *times.* The familiar experience of gravity, or the weight of objects, would be surprisingly increased, were we inhabitants of a globe as massive as the sun. This is because "*every particle of matter in the universe attracts every other particle*" *with a certain force, called gravitation. This force depends upon the mass and the weight of each of the attracting bodies.* You have already learned what is meant by the mass of a body. *The weight of a body is the downward pressure of that body under the force of gravity.* The theory, or law, of gravitation is sometimes called *Newton's law*, after its discoverer, Sir Isaac Newton.

On the sun, the force of gravity or attraction is such that all objects weigh twenty-seven times more (or *press down* twenty-seven times more heavily) than they do on the earth. "A man who on the earth weighs one hundred and fifty pounds, would there weigh nearly two tons; and, even if the footing were good, he would be unable to stir." [1]

Imagine the fate of a messenger boy at Christmas time laden with packages, if their destination happened to be the sun! For supposing each package weighed only two or three pounds here, upon the arrival of the messenger boy at the sun, the weight of each package, as well as the weight of his own body, would have increased twenty-seven times, and he would probably be crushed to the ground beneath the burden. In other words, he would feel the

[1] C. A. Young, "The Sun," p. 41.

force of the attraction, as well as the weight, increased proportionately.

"In ordinary life, mass and weight, at any place, are always in the same proportion to each other, so that we

Sir Isaac Newton.

need not make any distinction between them. But in astronomy, where we have to consider bodies in the heavens, the case is very different.

"As the quantity of matter in a body is always the same, while the weight varies according to the attraction

of other bodies, astronomers do not speak of the *weight* of heavenly bodies, but only of their *mass*. *All bodies having the same mass attract equally at the same distance.* Hence, the mass of a body may be determined by the attraction between it and another body at some fixed place. If we could cut a planet into pieces small enough to be brought to the earth and weighed, we could determine the mass of the planet by the weight of the pieces. As we cannot do this, we determine the mass by the attraction which it exerts on a satellite (moon), or on some other planet." [1]

In the case of the sun, we can determine its mass by its power in attracting the planets and keeping them circling in their paths or orbits, about which you will learn later. If the sun did not have this wonderful control over his family, the planets would wander aimlessly in space.

The Distance of the Sun from the Earth

The distance of the sun from the earth amounts to nearly 93,000,000 *miles.* When we try to realize this, we cannot but marvel still more at the attractive power that must be exerted to keep our planet from wandering about wherever it will. Perhaps one of the simplest illustrations of what this great distance really means is the following: "A bicyclist traveling 100 miles a day would be nearly 2550

[1] Simon Newcomb, "Elements of Astronomy."

years in making the journey, and if he had started from the sun in the year 1 A.D., he would by this time have covered only about three quarters of the distance. Light makes the journey in 499 seconds." [1]

In this connection it is interesting to note that *light, which travels about* 200,000 *miles a second, takes about eight and a quarter minutes in coming to us from the sun.* For this reason, when we look at the sun, we see him not in the place he actually occupies in the heavens, but in the place where he was eight minutes before.

Source of Light and Heat

The sun is an immense globe of gaseous matter, the temperature of its outer shell (called the *photosphere*) being probably equal to that of the most powerful electric furnace. The interior of the sun is still hotter, the heat increasing toward the center.

By means of this tremendous intensity of heat, the sun, although so great a distance from the earth, warms our planet by its fires, illuminates it by the splendor of its light, and pours forth on its surface electric and chemic influences, which are as necessary as light and heat for the welfare of the earth's inhabitants.

Were the heat of the sun withdrawn, the air would become chilled and the surface of the earth frozen to such

[1] C. A. Young, "Manual of Astronomy," p. 196.

a depth that no vegetation could live. Starvation and death would be the natural results of such a catastrophe. On the other hand, if the distance separating us from the sun were equal only to the distance separating us from the moon, our planet would be melted like a ball of wax. Or, as Professor Young graphically puts it, "if we could build up a solid column of ice from the earth to the sun, nearly two miles and a half in diameter, spanning the inconceivable abyss of 93,000,000 miles, and if then the sun should concentrate his power upon it, it would dissolve and melt, not in an hour, nor a minute, but in a single second: one swing of the pendulum, and it would be water; seven more and it would be dissipated in vapor."[1]

How the Sun's Heat is Maintained

"Ten million years ago the sun was nearly a million times wider than at present, and the simple principle which explains the fact that a redhot poker is a trifle larger than when it was cold must also apply to the sun.

"The most important question regarding the sun is the manner in which its heat is kept up. Supposing every particle of coal was taken from the earth and poured into the sun, how long do you think it would keep that orb going?

"It is a scientific truth that the entire coal supply of

[1] C. A. Young, "The Sun," p. 289.

the world would not give the sun's heat for more than the ten thousandth part of a single moment of time."[1]

How, then, is the sun's heat maintained? There are several theories, but the one most commonly accepted is that "*the heat of the sun is radiated from streams of matter constantly rising from the interior which radiate their heat when they reach the surface.* Being cooled, they fall back again and the heat caused by this fall is what keeps the sun hot.[2]

"A recent suggestion of the explanation of the sun's energy has been due to the discovery of radium. If radium is in the sun as it is in the bulk of the earth, then instead of a paltry twenty-four million of years' life allowed to the sun it would be 1,000,000,000 years!"[1]

In this connection, the reply of Professor C. A. Young in the summer of 1905, to the writer's question, "Is radium in the sun?" is of timely interest. "Radium in the sun may explain a considerable part of the sun's output of heat," said Professor Young, "so that the computed rate of contraction would be greatly diminished. Probably as radium is on the earth, it may be in the sun. Professor Snyder of the Philadelphia High School considers that he has found evidences of its presence, by comparing the lines reported in the spectrum of radium, with the known lines

[1] Quoted from an address delivered in London by the great astronomer, Sir Robert S. Ball.

[2] Simon Newcomb, "Astronomy for Everybody," p. 105.

in the solar spectrum. The apparent coincidences which he has found are not yet regarded as conclusive."

A time will come, beyond doubt, when the once brilliant sun will become "frozen and lifeless among its lifeless family of planets." However, the probability is that this may not happen for so many millions of years, that we need not feel alarmed with regard to the gloomy fate awaiting this radiant old monarch of the skies.

Revelations of the Spectroscope

Like a fairy tale it sounds, when we remember how inconceivably far away the sun is from the earth, to say that we can tell what old Sol is made of — or at least, astronomers can. Their magic wand is the *spectroscope*, a powerful instrument for analyzing the light of distant objects. By means of it, the observer can detect the presence of iron, copper, zinc, tin, and many other substances with which we are familiar. All these are present in the sun, not in the form in which we know them, but converted into glowing gases, so intense is the sun's heat.

The essential part of the spectroscope is a prism of glass. When a ray of light falls upon this prism, it becomes changed in appearance. Different portions of the ray are differently bent, so that when they emerge from the prism, they no longer travel side by side as before. The violet part of the light is bent most, the red least; the vari-

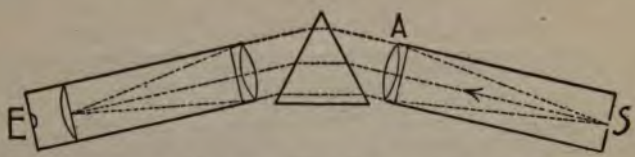
ous colors, from violet through blue, green, and yellow, to red, being bent gradually less and less. Thus the continuous *spectrum* (*ray of light bent by a prism*) is of rainbow-

A Spectroscope.

colored hue, violet at one end and red at the other, the order of the colors recalling the British poet Thomson's well-known lines: —

"First the flaming red
Sprang vivid forth; the tawny orange next,
And next delicious yellow; by whose side
Fell the kind beams of all-refreshing green.
Then the pure blue that swells autumnal skies,
Ethereal played; and then, of sadder hue,
Emerged the deeper indigo (as when
The heavy-skirted evening droops with frost),
While the last gleamings of refracted light
Died in the fainting violet away."

Examining a ray of light from the sun, we find that its spectrum is crossed by numerous dark lines. These dark



PLAN OF A SPECTROSCOPE.

EXPLANATION: Through *S*, a slit between two pieces of metal, the rays of light enter the spectroscope. They become parallel by passing through *A*, strike the prism and are refracted by it, and then pass through the telescope to the eye at *E*.

lines occupy the spaces where bright lines should be, and indicate that the gases corresponding to those lines are to be found in the *atmosphere*, or outer shell, surrounding the sun. The atmosphere of the sun is cooler than the interior. For this reason, the gas or vapor in passing from the interior through this outer shell absorbs precisely those rays of which its own spectrum consists.

For instance, *every element when reduced to vapor glows with its own characteristic color.* Consequently, a chemist

TWO SPECTRA AS SEEN IN A SPECTROSCOPE.

One spectrum above the other, showing the correspondence between the bright and dark lines.

can detect the presence of an element by its color. Iron produces a green line; sodium, a yellow; while strontium

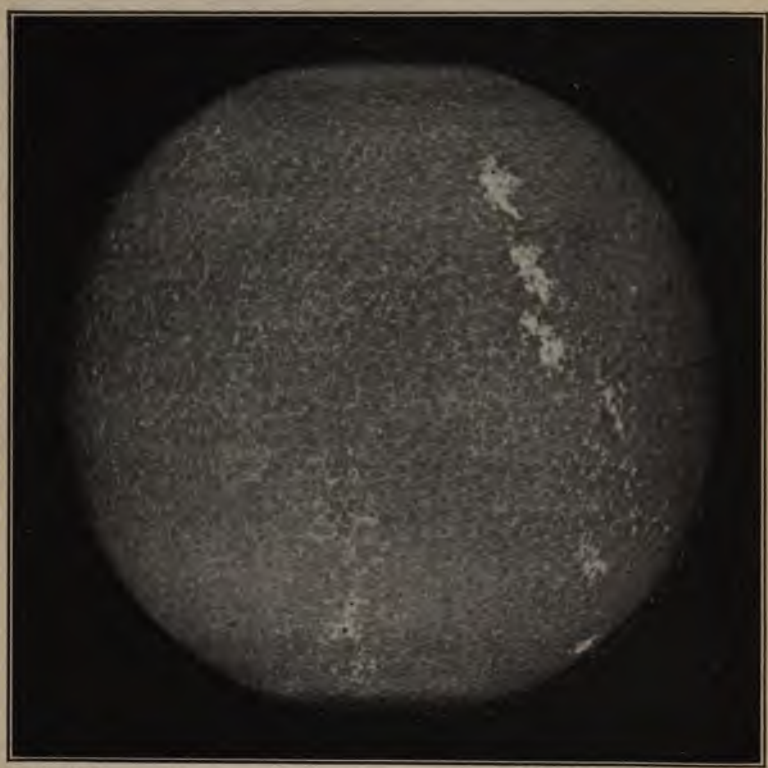
gives a peculiar red light, which no other substance gives. The spectrum of sodium vapor consists of a pair of bright yellow lines called the *D lines*, so near together that they are often treated as one line. Lithium gives a splendid red line; hydrogen three lines, one red, another greenish blue, and the third dark blue. When the dark lines corresponding to the bright lines indicating these elements are to be found in the solar spectrum, we know that the sun's atmosphere contains the vapors of iron, sodium, hydrogen, strontium, and many other metals.[1]

The Photosphere, or Light Sphere

The sun's visible surface, or photosphere, is the part of the sun which sends us light and heat. When examined with a telescope, it presents the appearance of a grayish background strewn with snowflakes. The snowflakes are probably bright clouds floating in a less luminous atmosphere, as when a cloud tinged with the silvery hue of dawn is outlined against a gray sky. Sometimes these sun-clouds, if we may so term them, are from 400 to 600 miles in length, and for the most part are as broad as they are long. Certain bright streaks called *faculæ* (from the Latin word *facula*, a little torch) are to be seen here and there on the sun's surface. When near the edge of the sun, they seem like the crested waves of a raging sea,

[1] For further details, see Young's "Manual of Astronomy," pp. 226–227.

for the sun's surface is not only aglow with intense heat, but is agitated with furious storms.



After Hale.

THE SURFACE OF THE SUN, SHOWING SUN-CLOUDS OF CALCIUM VAPOR.

The spectroscope has enabled us to determine that the clouds which form in the photosphere are composed of the vapors of iron, copper, zinc, and other elements, and also

that the rains falling from these clouds are torrents of molten metal.

Sun Spots

At times tremendous disturbances take place on the sun, causing vast openings in the photosphere, called *sun spots*. These represent a region from which the bright clouds have been cleared away for a space of over many millions of square miles. The *umbra* (from the Latin *umbra*, a shadow), or dark center of the spot, varies from 500 miles to 50,000 miles in diameter. The *penumbra* (Latin *pæne*, almost, and *umbra*, shadow), or grayish portion surrounding the umbra, is sometimes 150,000 miles wide, though that is unusual. In appearance, the penumbra resembles rushes drooping over a pool of water. The depth of sun spots seldom exceeds 2500 miles, and more often is between 500 and 1500 miles.

If, as has been suggested, these spots are deep openings in the luminous photosphere of the sun, our earth at the bottom of such an abyss would be "like a bowlder in the crater of a volcano!"[1]

[1] On February 27, 1905, Professor John A. Brashear, of Allegheny, Pittsburg, announced that a group of spots of alarming size had made their appearance on the sun's surface. "They came into view about 9 A.M. yesterday," he recorded, "and have no doubt been observed all over the world. They cover an area of possibly 3,000,000,000 square miles, and are much more active than the spots which occurred last month. Last year 127 different groups of spots appeared on the sun, but none so large or ominous as those which first appeared yesterday."

Some spots change rapidly in appearance, resembling vast whirlpools, seething and foaming. Suddenly, becoming ingulfed by the surrounding atmosphere, they tumble "pell-mell into the cavity" and form a facula, or bright

A Sun Spot.

streak, to replace the spot. Other spots last for days or even weeks at a time, while in one instance (1840–1841) a spot remained visible for eighteen months. The spots are more numerous in some years than in others, and sometimes none will be visible for several days.

Solar Cyclones, or Rotation of Sun Spots

The movement, or rotation, of a sun spot causes a violent upheaval of the cloud-strewn surface of the sun's photosphere. Storms undoubtedly rage there, in which fiery masses of vapor are flung forth from the blazing depths of the sun to a height far exceeding the diameter of the globe on which we live.[1]

We know that these cyclonic storms, though they seem to take place quietly, must in reality be accompanied with an almost inconceivable uproar and tumult. Just as the great distance causes the clouds floating in the sun's atmosphere to resemble snowflakes, though in fact they cover a space from 400 to 600 miles in extent, so distance and the absence of a medium to convey sound reduce to utter silence a noise and tumult compared with which the roar of the hurricane, the crash of the thunderbolt, and the groaning of the earthquake are as absolute stillness.

Terrestrial Influences of Sun Spots

Probably the strangest fact concerning sun spots is the undoubted connection between the appearance of a large number of them and the occurrence at the same time of magnetic disturbances on the earth.

On the 1st of September, in the year 1859, vivid *auroras*, or northern lights, occurred in latitudes where auroras are

[1] Diameter of the earth is about 7920 miles.

as rare as rain in Peru. They were observed at Rome, in the West Indies, and even within eighteen degrees of the equator. On this same occasion, it was impossible in many places to send telegraphic messages. "At a station in Norway," says Sir John Herschel, "the telegraphic apparatus was set fire to, and at Boston a flame of fire followed the pen of Bain's electric telegraph, which writes messages upon chemically prepared paper."

The cause of these unusual magnetic disturbances was traced to a very large sun spot. While two well-known English observers, Mr. Carrington and Mr. Hodgson, were making their usual daily observations of the sun, they saw, at the same time, though in different places, two bright objects, shaped something like two new moons, each about 8000 miles in length and 2000 miles wide. They were at a distance of some 12,000 miles from each other, that is, they were so far apart that our planet could roll between them and still leave over 4000 miles to spare.

These bright masses, brighter many times than the sun's photosphere (which is 150 times as bright as calcium light), suddenly appeared at the edge of a great sun spot. They moved eastward over the spot in parallel lines, growing smaller and fainter, until, after a period of about five minutes, they disappeared. In this short time they had overed a distance of nearly 36,000 miles. The event omes none will be of a remarkable magnetic storm. From

August 28 to September 4 of this same year, auroras were visible every night all over the world.

Although there is no doubt that a connection exists between storms on the sun and magnetic storms on the earth, yet, according to Professor Young, we do not know "whether the solar disturbance causes the terrestrial or whether both disturbances are due to some external influence."

The Aurora Borealis

The aurora, visible only at night, is a scene of imposing grandeur. The auroral streamers, flashing silently hither and thither, now fade entirely from view and again glow with a splendor intense and awe-inspiring. Outlined against the sky, these quivering rays of purest white shoot upward from the horizon, spreading outward like a fan. At other times they resemble golden draperies floating overhead, yet apparently so near the earth that one almost expects to hear the rustling of their folds as they wave to and fro.

Again, the aurora is a luminous bow of white or ruddy hue, darting forth rays that fill the sky. Mounting upward to the zenith, these rays unite in forming a *corona*, or crown, which flashes bright rainbow-colored jets in all directions. The sky at this moment presents the appearance of a cupola on fire, vibrating with the blue, green, yellow, red, and white coronal streamers. But this bril-

liant spectacle lasts only for a few minutes — the crown fades, and airy, cloudlike masses quivering with changing color float against the background of the dark sky. The stars which had grown dim in the auroral glow now shine forth with renewed luster, and the dark polar night, somber and mysterious, resumes its sway over the icy solitudes of earth and ocean.[1]

The Chromosphere

Outside the photosphere, or shining surface of the sun, lies the *chromosphere* (derived from the Greek *chroma*, color, and meaning color sphere). It is so called on account of its brilliant scarlet hue, and when seen through a telescope at the time of a total eclipse of the sun has been aptly described as resembling a "prairie on fire." From this burning ocean, which is 5000 to 10,000 miles in depth, great masses of glowing gas are flung upward with a velocity of 50 to 200 miles a second.

Solar Flames

Solar flames, or *prominences* as they are called, are irregular masses of fiery gas that jut out from the edge of the sun in many fantastic forms. Some look like rosy clouds floating above the surface of the sun, or connected with it

[1] The above is a condensed account of the aurora, as suggested by a description given by Mr. Charles Martius, who observed a great number of auroras in Spitzbergen in 1839.

by slender columns. Others present the appearance of interlacing branches of trees, or of spray from a fountain shooting upward with a greater velocity than we can imagine and dropping in a rain of fire upon the blazing

After Hale.

SOLAR FLAMES ON THE EDGE OF THE SUN.

sun beneath. These brilliant and active explosions are known as *eruptive* prominences, since they form and disappear rapidly.

On October 7, 1880, an eruptive prominence was observed by Professor C. A. Young, of the Princeton Observatory, New Jersey. He made his observation at 10.30 A.M., when the flame was visible on the southeast *limb*, or edge, of the sun. It was then about 40,000 miles high and attracted no special attention. Within half an hour, the flame had become very brilliant and had doubled its length. During the next hour it rose upward, until it reached a

height of 350,000 miles. Forty globes the size of the earth, placed one upon the other, would not have reached the tip of this mighty flame. At this climax, the energy of the tumultuous outbreak was at last exhausted. The flame broke up into fragments, and by 12.30 P.M. — an interval of only two hours from the time it was first seen — it had completely faded away.

The cloudlike masses of gas, which often remain unchanged for days, are called *quiescent* prominences. They are usually of enormous size, being from 50,000 to 100,000 miles in height. Twelve globes as large as the earth, piled one upon the other, would not reach the top of a cloud 100,000 miles high.

The Corona

Farther away than the color prominences, there extends around the outermost edge of the sun a halo of glory known as the corona, or crown of the King of Day. Near the sun it is dazzlingly white, but beyond it shades off so gradually that no distinct outline can be seen. It rests on the photosphere and seems to be a continuation of the atmosphere of the sun. It is composed of luminous gas and fog, or of dust of some kind, reflecting the light of the sun. Many of the peculiarities of the corona are as yet unexplained, since it can be observed only during the brief moments of a total solar eclipse, that is, when the

glare of sunlight is completely hidden by the dark globe of the moon coming exactly between the sun and the earth. Nevertheless, we do know that the corona is the most marvelous of all celestial wonders.

An amusing story is told about Professor Snell, of Amherst College, and an inattentive pupil in his class. The professor, wishing to arouse the pupil's interest in the corona, the subject then under discussion, suddenly asked him, "What is the corona?"

The boy stammered and looked confused for a few moments, but finally a gleam of intelligence illumined his face as he replied, "Well, sir, I did know, but I have forgotten." "Forgotten!" exclaimed the professor in assumed dismay, "to think there is only one man in the world who knows what the corona is, and he has forgotten!"

Zodiacal Light

Extending from the sun both east and west along the great circle which the sun appears to describe each year among the stars is a faint pyramid of light known as the zodiacal light. It owes its name, doubtless, to the fact that its pathway is outlined by the twelve constellations, or groups of stars, forming an imaginary belt in the heavens called the *zodiac*. If the zodiacal light were suddenly extinguished and the stars were to shine as at night, we would see a zodiacal constellation in the background.

The zodiacal light is due probably to the reflection of sunlight from small particles of dust revolving around the sun in a comparatively thin, flattened ring which extends far beyond the path of our planet earth. The zodiacal light can be seen in the evening, after twilight, and in the morning before dawn. In the evening it is best seen in February, March, and April, and in the morning during the autumnal months.

The light has been described as exquisitely delicate and ethereal in appearance, now growing dim for a few minutes and then suddenly glowing with renewed brilliancy. Some have described it as ruddy in hue, others as yellowish, and still others as a pearly white. We may take it for granted that of all the forms which light takes, the zodiacal light is the most rarely beautiful. It is not altogether unlike the Aurora Borealis, with which it has frequently been compared. Owing to the fact that the zodiacal light has been seen during a total eclipse of the sun, it is to be inferred that its light is inferior in brilliancy to that of the corona.

CHAPTER II

TOTAL ECLIPSES OF THE SUN

"As when the Sun, new risen,
Looks through the horizontal misty air,
Shorn of his beams; or from behind the Moon,
For dim eclipse, disastrous twilight sheds
On half the nations; and with fear of change
Perplexes monarchs."

—MILTON.

THE word "eclipse" comes from a similar word in Greek, meaning a failing or forsaking. *A total eclipse of the sun* (or entire failing of light) *takes place when the moon comes exactly between the sun and the earth.* Since the moon is a sphere, it casts, like all other spheres, a shadow of the same general shape as itself, that of a long, narrow cone stretching from the sun away into space. The tip of the shadow trailing along the earth has been compared to the point of a lead pencil marking a line on a whirling ball that represents the earth.

The shadow cast by the moon is called the umbra, or dense shadow, because the sun's light is entirely withdrawn from the part of the earth's surface over which it trails. The average breadth of the shadow is about 90 miles. On each side of it is a less dense shadow called the

penumbra. The width of umbra and penumbra together is rarely more than 160 miles.

The shadow trails eastwardly, and the earth, as it rotates, carries the observer eastward in the same direction as the shadow, which glides through space with a velocity exceeding 2000 miles an hour. As the moon gradually approaches the point where it will be directly between the sun and the earth, a peculiar darkness is observed, and the light of the sun and sky grows dim. At the instant of totality, or when the sun is entirely covered by the moon, the solar corona flashes out and the total eclipse of the sun begins. The observer is then within the umbra or dense shadow, which usually requires less than three minutes, and never more than six, to trail over any one place.

In order to observe this wondrous spectacle of the corona, many astronomers have been willing to travel thousands of miles to most inaccessible regions. Total eclipses of the sun are announced years in advance, and the pages of the *Nautical Almanac* record the exact time of an eclipse for any part of the earth.

Author's Eclipse Expedition to Bodö

On August 9, 1896, a total eclipse of the sun was scheduled, its pathway crossing Norway and Siberia, and ending at Yezzo, an island of Japan bordering on the Sea of Okhotsk.

Arrangements had been made for the author's party to observe the eclipse from Bodö, a small fishing village in western Norway, twenty miles south of the Lofoten Islands. On our arrival there we were informed that we should have to climb a hill 2000 feet high if we wished

THE HARBOR OF BODÖ, SHOWING THE EXPEDITION SHIP AT ANCHOR.

to observe the eclipse. So our ship was anchored near the Kunnen promontory, twenty miles south of Bodö. Although our experience was of little value so far as scientific research was concerned, yet it was full of novelty, being our first glimpse of this glorious spectacle.

On the morning of the eclipse we were awakened at two o'clock — for it must be remembered that we were in the region of the Midnight Sun, where the sun sets and rises at most unusual hours. We hurried on deck. The sky was blue and clear, save for a few fleecy white clouds edged with the palest pink. Behind the intervening hills gleamed a rosy light merged in a golden mist, for the sun had already risen and was about three or four degrees above the horizon. About three o'clock, Greenwich mean time, attention was called to a black notch on the upper right edge of the sun's disk. This was the moon, which soon became plainly visible to all, as it passed between the sun and the earth with slow but steady motion. Gradually the surrounding landscape lost its brilliant color. The Arctic Ocean all around us was calm as a summer lake, and the breezes setting toward land were almost balmy. On the top of the Kunnen promontory floated a mass of gray cloud. The mountains were partly lost in shadow, while the sheen of the ocean had dwindled into a narrow pathway. A silvery radiance overspread the golden tints of sea and sky.

It is impossible to describe the weird effect produced by this strange, unearthly sight. It can be compared only with the rare glow one sees when the sun comes out slightly obscured after a thunderstorm. Slowly this silvery tone faded into a more somber hue, and the faces of the people on the ship looked ghastly in the waning

light. The air became decidedly chilly, and the darkness seemed literally falling from above, like a curtain let down from the sky. A star flashed into view near the zenith and then seemed veiled again in mist, but as our eyes became accustomed to the gloom we could see it twinkling brightly as before.

It was an indescribably fascinating sight, and even the sun was forgotten by those who were watching the strange effect of the approaching shadow. The sea gulls that had been circling around our ship flew away affrighted. In silent awe we awaited the moment of totality, for the merest outline of a crescent was to be seen. Then a repressed but universal cry was heard echoing from one end of the ship to the other. Totality had come so suddenly that it was impossible to stifle an exclamation of surprise.

The sun was hidden from view by the moon, which hung like a dark globe in mid-air. All around it glowed the glorious corona of the sun. No painter ever wielded brush who could reproduce that matchless silvery light against which gleamed the solar flames of ruby hue. Overhead the stars were visible as at night, and the planets — Mercury, Venus, and Jupiter — shone brightly against the ashen background of the sky. An instant before totality was over a vivid gleam of red outlined the western edge of the moon. Next moment the sun burst forth in a blaze of glory, and the corona vanished.

The dream of our long voyage was over, the skies paled in the sun's luster, the chilliness of the air was replaced by warmth, and the frightened sea gulls returned to the ship. Only one minute and thirty-five seconds had that scene of impressive beauty lasted, but it could never be forgotten. It was as though we had paused for a moment on the threshold of the Infinite, obtaining a fleeting glimpse of the glories beyond!

Eclipse Expedition, May 28, 1900

During the year 1900 a total eclipse of the sun took place on the 28th of May, beginning at sunrise. The pathway of shadow came in contact with the earth on the Pacific coast of Mexico, and then crossed the northwest angle of the Gulf of Mexico, striking the United States at Louisiana. Traveling in a northeasterly direction, it passed over New Orleans and crossed in succession the states of Mississippi, Alabama, Georgia, South Carolina, and North Carolina, reaching the Atlantic Ocean at Cape Henry in Virginia. The chief towns near the central line of the shadow were Columbus in Georgia, Raleigh in North Carolina, and Norfolk in Virginia.

The leading observatories in the United States had representatives stationed along the central pathway of shadow. Once more the author had an opportunity of witnessing a total eclipse, this time joining a party which

had made arrangements to see the eclipse from Virginia Beach, Virginia.

Leaving Norfolk, Virginia, at six A.M. on the morning of the 28th of May, we arrived at the beach about five minutes past seven. The photographer of the party selected a suitable site for his camera, while others prepared to observe the approaching shadow, the landscape effects, and the elusive shadow bands.

The sky was blue and almost cloudless, and the air warm and pleasant, but the temperature fell several degrees during the hour preceding the eclipse.

We first noticed the moon on the western edge of the sun. This was about twenty-three minutes to eight. Within a quarter of an hour, the blue tint of the sky had merged into gray, though in the immediate neighborhood of the sun the sky remained comparatively bright. When the sun was half hidden by the moon, the sky assumed an ashen hue as at eventide. About this time we noticed the swallows circling around overhead, as though at the approach of a storm. The twittering of the birds in the nearest trees, calling to their little ones, showed that they were under the mistaken impression that it was evening. A negro coming from an adjacent field feebly urged the mule he was driving to hurry, and we could see him casting terrified glances at the sky, which momentarily grew darker. It was a scene well fitted to alarm the ignorant, and to fill even those who knew its

meaning with a strange feeling of awe, as at something uncanny.

Meanwhile, when the sun was a little more than half covered, we amused ourselves noting the crescent shapes assumed by the light as it sifted through the leaves of the trees. As we were stationed some distance from any large trees, we gathered some branches of sweet bay that we found growing on the beach. Holding these over a white sheet we had prepared for our observations of the shadow bands, we saw clearly outlined crescent-shaped patches of light instead of round patches, as is usually the case.

As the moon advanced still farther over the sun's disk, these crescents became more and more marked, so that by watching them we could tell the progress of the eclipse in the sky. A mere pinhole pricked in a paper through which the sunlight filtered produced exactly the same effect, only in miniature. The explanation is simply that light proceeding from any object, and passing through a small opening, throws an image of the same shape as itself. Thus, if a beam of sunlight passes through a hole in a window blind, its image is seen on the floor or wall of a room as a round patch of light, the same shape as the sun.

About ten minutes before totality, we began to make our preparations for observing the shadow bands which make their appearance just before and after totality. We placed two white sheets on the ground, and just a mo-

ment before totality, and for a few seconds after, these strangely elusive, flickering shadow bands drifted rapidly over the white surface prepared to receive them. They resembled the faint and indistinct outline of the rippling waves of a calm, sunlit sea reflected on the walls of a stateroom of a steamer in motion. Their rapidity of motion has been compared to that of a fast-flowing tide.

At the moment of totality, the shadow bands vanished and the dense shadow of the moon swept over us like a mighty wave, advancing at the rate of a thousand miles an hour and encircling us in its gloom. The purplish hue of the sky was reflected on the waves as they rippled along the beach, the purple merging into a deep orange tint near the horizon. The sun was now entirely hidden by the moon, around which glowed the dazzling white inner corona of the sun, the silvery rays of the outer corona being distinctly outlined against the sky. These coronal streamers extended outward in the direction of planet Mercury and about two thirds of the way and downward in the direction of Venus. Only the planets Mercury and Venus, and Castor, the bright star in the constellation Gemini, the Twins, were visible during totality.

On returning to Norfolk, Virginia, we were informed that all the inhabitants had turned out to observe the eclipse, and that thousands of cameras and telescopes had

been leveled at the sun. As a result, some very good views and photographs were obtained. Shortly before, during, and after totality, five-minute observations were made to determine if the eclipse affected the weather, with regard to change in temperature, dew-point, humid-

THE CORONA, AS PHOTOGRAPHED BY THE PRINCETON ECLIPSE EXPEDITION AT WADESBORO, NORTH CAROLINA, IN 1900.

ity, and wind or clouds. Although we did not make a specialty of such observations, we could not help noting, during the progress of totality, that the air became chilly and that a breeze sprang up from the sea. The ground was covered with dew at the time when only a slender

crescent of sunlight was visible, or a minute or so before totality. The writer, who had placed her gloves on the ground while making notes regarding the shadow bands, picked them up after the eclipse was over and found them damp with moisture.

Eclipses of 1901, 1903, and 1904

The next total eclipse of the sun took place on May 17, 1901, its path traversing the islands of Mauritius, Sumatra, Borneo, and New Guinea. The duration of totality in Sumatra amounted to six and a half minutes, the greatest observable eclipse of the last fifty years. Results of great value were obtained by Professor Perrine, in charge of the William E. Crocker expedition from the Lick Observatory.

On September 28, 1903, a total eclipse of short duration occurred in the southern Indian Ocean. No effort was made to secure observations, as the shadow did not pass over land, unless it passed within the closed South Polar continent.

Another eclipse, occurring on September 9, 1904, was practically unnoticed for this same reason. This eclipse was so discourteous to astronomers as to waste its beauties over the waters of the Pacific Ocean, without touching any known islands, terminating on the coast of northern Chile about six minutes before sunset.

However, there was a small island[1] close to which the central line of shadow passed, where the duration of totality exceeded five minutes.

[1] It was named Christmas Island by Captain Cook, because he spent his Christmas there in the year 1777, the day after he made its discovery. It is of interest to add that from this island Captain Cook and his companions observed an eclipse of the sun on December 30, 1777. Clouds prevented their seeing the beginning of the eclipse, which took place at 9.30 A.M., and the intense heat made it impossible to watch the spectacle long.

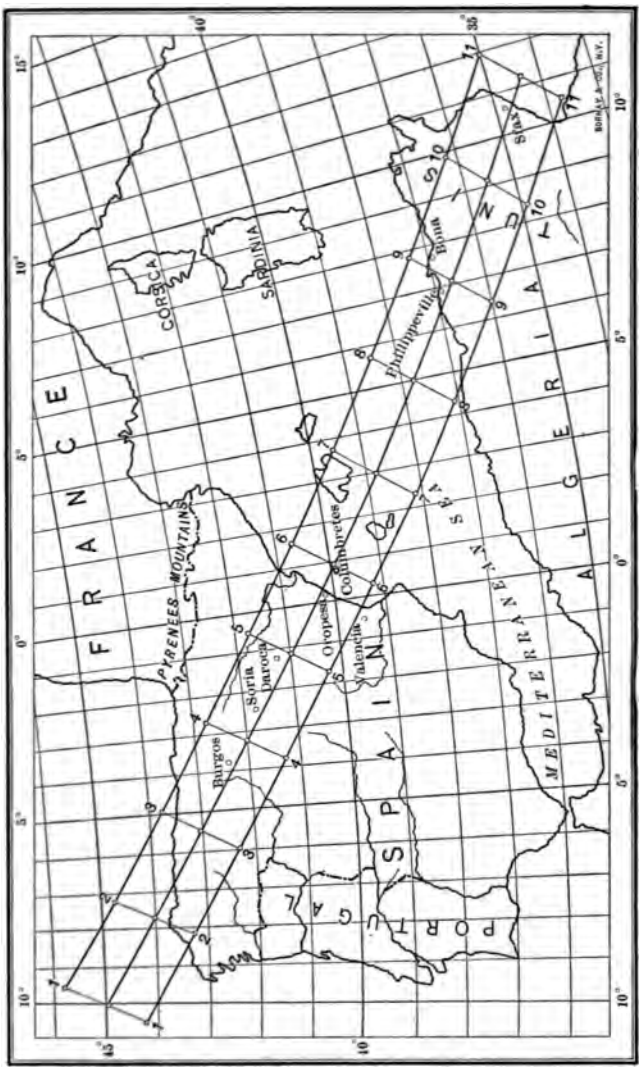
CHAPTER III

ECLIPSE OF AUGUST 30, 1905

THE next observable eclipse, that of August 30, 1905, was looked forward to with unusual interest. The shadow path began at sunrise south of Hudson's Bay, entered the Atlantic Ocean a short distance north of Newfoundland, crossed northeastern Spain, northeastern Algeria, and northern Tunis. It then passed centrally over Assouan on the Nile, and ended at sunset in southeastern Arabia. The eclipse lasted two and a half minutes on the coast of Labrador, three and three quarter minutes in Spain, and a little over two minutes at Assouan.

Results of the 1905 Eclipse Expeditions

On account of the prevalence of clouds during totality at several stations, the hopes of astronomers were not fully realized at the eclipse of August 30, 1905. The expeditions sent to Labrador and to Newfoundland were, in fact, entirely unsuccessful. The weather was so stormy previous to the 30th, that it was no easy task to set up and adjust the strong battery of observing instruments. On one occasion a violent squall from the north-



MAP SHOWING THE PATH OF THE ECLIPSE OF 1905 THROUGH SPAIN, ALGERIA, AND TUNIS.

west overturned a solidly built hut and a heavy iron pier with the telescope attached. However, everything was repaired before the eclipse day, and good results were assured if only the sky should be clear of cloud. Unfortunately the sky was completely overcast on the morning of the eclipse. There was no break before or after totality, and by the deep gloom and darkness alone did the scientists know that the eclipse had begun, was progressing, and was over.

As one of the observers afterward remarked: "An astronomer's life at best is not an easy one, but surely the hardest lot of an astronomer is when he goes on the forlorn hope of an eclipse expedition. For science demands that no available station be left unoccupied, and, though we knew that the prospects of fine weather in Labrador were not of the best, we must not neglect the chance of obtaining photographs near sunrise of that same corona that would be seen near noon in Spain, and near sunset in Assuan.

"But perhaps the astronomers at the Northwest River post are not the most to be commiserated of any of the astronomers on the Labrador coast. The inland locality was chosen deliberately as being beyond the reach of the fogs which prevail on the seacoast. But it was right that the region on the seacoast across which the shadow should pass should be occupied also, and here the astronomers from the Lick Observatory determined to pitch their

camp. At first they chose a site at Indian Tickle, on one of the tiny islands close to the mainland.

"Later, in hope of better weather conditions, they removed their camp from Indian Tickle to Cartwright, a Hudson Bay post on the mainland, where they escaped fog indeed, but had the more heartrending experience still of finding a low, dense, local cloud obscure the sun and its surroundings for twenty-five minutes, during which the moon passed across the face of the sun and the eclipse was accomplished." [1]

The Lick observers at St. John's, Newfoundland, also experienced a total failure, owing to clouds.

Observation of Solar Eclipse at Sea

Meanwhile the shadow swept across the Atlantic in the direction of Spain, the observers on the North German Lloyd steamship *Main* (when about 320 miles east of Sandy Hook) getting a fine view of the partial eclipse. The passengers on the steamship *Lucania* also had a splendid opportunity to observe the phenomenon.

The accompanying diagrams,[2] drawn at the time, by Captain J. B. Watt of the R.M.S. *Lucania*, show the apparent path of the moon across the sun's surface, and the apparent positions of the sun and moon at the times

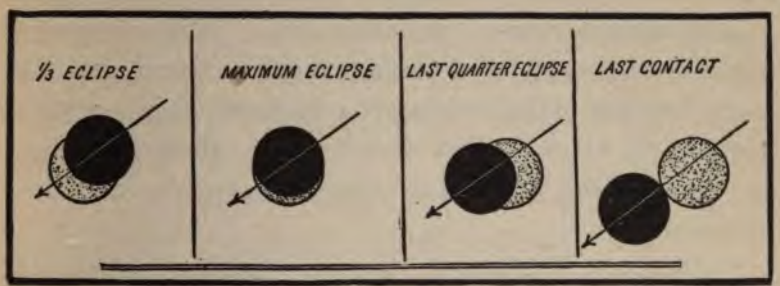
[1] *New York Times*, September 24, 1905. Abstract from an article entitled "Failure in Labrador," by A. S. D. Maunder.

[2] Reproduced by permission from *Scientific American* for September 16, 1905.

given. The observations were taken during a westward passage.

The following account is given of the eclipse in mid-Atlantic, as viewed by a party of travelers heading east-northeast for the southwestern corner of Ireland : —

"Cold, rainy weather and dull skies for four days previous had given little promise of fair conditions for



THE APPARENT PATH OF THE MOON ACROSS THE SUN'S SURFACE.

the moment to which we were looking. What chance was there of a clear sky just for that one important hour upon which all depended? And what chance of our being near or even on the path of total obscuration? We knew that we were not far off it, that was all. But the day broke bright with a fresh northeast wind, and through a waft of fleecy clouds the sun broke often enough to raise our hopes high.

"At ten minutes past ten, the first sign of the moon could be seen by field glass at the western point of the

sun's orb — to use an unscientific but simple mode of expression. Gradually more and more of the sun's surface was hidden by the moon, the lessening sunlight producing a peculiar effect on the scene. The eclipse missed being a total eclipse by two minutes of the sun's arc, but even so, the results were marvelous. Overhead was the copper-black moon, like a window closely shuttered except where, through a narrow slit, poured floods of golden light with a throbbing motion which seemed to the eye to expand, contract, and again expand, as if the inner forces of light were trying to burst their unnatural barrier; all above us the cloudless sky, shading in place of the familiar blue, into tones of sapphire and deep ultramarine.

"The planet Venus could be seen twinkling on high, 'in deep amaze,' no doubt, at her own daring. Around us, the boundless expanse of swelling ocean, a surface of deep violet hue, except for one lane of pale gold which pointed to the sun, and a few wave crests which glinted against the rays into sickly yellow, amber, and green. And we ourselves? Surely for the moment we might have served as a suitable illustration for the poem of the Ancient Mariner. The light fell on haggard faces, lusterless eyes, and livid lips. The deck itself was ashy gray, and every footstep upon it had a certain air as of the movement of spirits in twilight.

"'We were a ghastly crew.'

"But soon the tide of life began to flow again. Every minute light, warmth, and color returned, and by 11.30 the vision which had attended us on our way for those few minutes had faded into the light of a common day once more, yet the sunlight was still of a lemon hue, the sun's orb only half uncovered, and the last traces of the retreating shadow had not passed away till the noontide hour. Perhaps the most impressive feature of an event which few of us may witness again was the intense illuminating power of the sun's rays when so small a fraction of its orb was free from obscuration. Yet what a difference between the

"'Holy light, offspring of Heaven first-born,'

and that eerie gloaming in which we stood!"[1]

Eclipse Observations in Spain

The cable reports received from Spain announced that the observations made by all the parties under the direction of Rear Admiral C. M. Chester, commander of the special squadron sent to Spain and to the northern coast of Africa, were entirely successful. As previously stated, two separate stations were chosen in Spain, — one near the city of Valencia, the other at Daroca in Aragon.

For weeks before the eclipse the astronomers and their assistants had been actively engaged in setting up

[1] Abstract from *The Westminster* for September 1, 1905.

the telescopes, cameras, and spectroscopes, and in adjusting them carefully in readiness for the three minutes and forty-five seconds during which the total eclipse of the sun would take place.

One of the largest cameras ever constructed was used at the Valencia camp for photographing the corona. It was seventy feet long from the front of the lens mechanism to the back of the box, the latter being in reality a small house representing a dark room. What corresponds to the bellows of a portable camera was a long framework resembling a windmill tower lying in a horizontal position. In front of the great lens, seven and a half inches in diameter, was a circular mirror, very highly polished, rotated by clockwork so as to follow the sun from its rising to its setting and reflect it into the lens.

The center of the sun was thus kept focused upon that of the great 18 by 22 dry plate in the plate holder within the little house at the rear end of the bellows. The black image of the sun focused upon the plate was about seven inches in diameter, giving abundant room for the great streamers and halo of the corona, visible only during the few precious moments of totality. For three days before the eclipse frequent drills were held, in order that all might become familiar with their work on eclipse day.

The following is a brief extract from an interesting article, contributed to the *New York Times*, September 24,

by Dr. S. A. Mitchell of Columbia University, New York City, concerning his experience at the city of Daroca, on the day of the eclipse: "About ten minutes before totality, the landscape appeared weird and unnatural, as if a violent storm were about to take place. All nature seemed hushed and quiet, as if in preparation for some great catastrophe, and birds and cattle prepared for rest, as though at eventide. The shadows underneath the trees, instead of being little spheres, assumed the appearance of crescents, which were indeed counterparts of the sun itself.

"But while we were watching the ever changing landscape effects, an immense shadow swept over the ground at terrific speed, and next moment the sun was entirely hidden from view. Words can scarcely convey an idea of the magnificence of the sight that flashed out in an instant. Around the place where the sun had been could now be seen a delicate pearly light, the wonderful corona, or crown of glory which surrounds the sun. Indescribable is the infinite beauty of its filmy wisps of light, interwoven with a delicate tracery of curves and streamers. The wondrous sight remained visible during only three minutes and forty-five seconds, when, with the first reappearance of sunlight, the corona disappeared and the observations of the eclipse were practically over.

"The form of the corona was exactly as predicted beforehand by the astronomers."

Eclipse at Burgos

It must be stated, to the credit of the Spanish government, that as early as 1901 the Madrid Observatory officials began to make definite preparations for the eclipse. First, by the issue of a very good map of the path of the central line across Spain, and afterward by the issue of additional maps and a pamphlet of suggestions and advice, Don Francisco Iniguez (Inn-e-gueth), director of the observatory at Madrid, proved untiring in the energy and patience with which he accomplished the self-imposed task of removing any obstacles which might have proved a barrier to the success of the astronomers who contemplated observing the eclipse in Spain.

Having made definite arrangements for observations which were to be made of the partial eclipse at Madrid, Don Iniquez went to Burgos, for the purpose of directing the final arrangements for the astronomer's camp at the site of Campo de Lelaila, situated at a distance of two or three miles from Burgos and one hundred and fifty feet above its level, just even with the top of the cathedral spires. On this elevation were erected twelve tents, representing the Spanish, French, English, American, German, Dutch, and Scotch parties.

Naturally, the "eclipse-week" in Burgos was one of intense excitement for all concerned, spectators as well as astronomers, and the hospitality of the little village was

taxed to its utmost. The rooms in the only hotels—three in number—were engaged months ahead, and exorbitant prices were charged, generally £30 ($150) per head and upwards.

When the author's train reached Burgos, two or three days before the eventful day, the village was filled

The Cathedral Spires at Burgos.

to the utmost with astronomers, and with visitors from every point of the globe. Hundreds thronged to the station to get a glimpse of us. The streets were lined with the curious; and women sitting by the roadside with their children in their arms, men of swarthy aspect and

brigand type, and dark-eyed Spanish maidens with roses in their black hair and with mantillas coquettishly draped around their heads, added to the picturesqueness of the scene. Flags waved from balconies and adorned the principal buildings, and for a few moments we were under the

THE ARRIVAL OF THE KING OF SPAIN AT BURGOS.

mistaken impression that this gala display was all in our honor, but we were soon disillusioned.

"El Rey! El Rey!" (The King! The King!) was the cry that we heard on all sides, and then we learned that the king of Spain was coming to Burgos to see the eclipse. He arrived that same evening, taking up his residence for the time being in the Carthusian monastery on the outskirts of the city.

The day before the eclipse, the king visited the camp of the astronomers, and reviewed, so to speak, the arrange-

KING ALFONSO LISTENING TO AN EXPLANATION OF THE USE OF THE TELESCOPE BY ONE OF THE ASTRONOMERS OF THE BRITISH ASTRONOMICAL ASSOCIATION.

ments which were being made for observations of the eclipse. He examined the various astronomical outfits

with much interest, conversing affably and with the greatest ease with the directors of each expedition in their own language. As there were French, German, Dutch, and English astronomers, this was no easy matter. During his visit to our camp there was a slight shower of rain, and the king took refuge in the English camp, where he seemed greatly entertained by the members of our party who made him welcome. The Spanish astronomers, as was to be expected, gave a most cordial greeting to their king when he entered their tent, over which floated the Spanish flag.

Meanwhile, the astronomers continued their preparations, although many a one felt anxious and discouraged as he gazed at the gray sky heavily massed with clouds. Was this the Burgos of which they had heard, "where blue skies were promised without fail, and clouds were unusual?" For nearly two weeks, during which the astronomers had been making their preparations, cloudy skies had been the daily programme, and there seemed little chance of any change on August 30.

However, the morning of the eclipse promised fairly well, for the sky was practically clear of clouds save for a few which presented a rather threatening appearance low down on the horizon. Later on in the day, they were destined to make their appearance when least wanted, and almost to cause a total eclipse of a kind not expected.

Breakfast on the morning of the eclipse could not be obtained in our overcrowded hotel without a desperate struggle, and coffee and rolls were at a premium, eight pesetas, or about one dollar and a half, being the usual charge. Even then, one had to accept coffee in any way he could get it. Cups giving out, glasses and sugar bowls were used as substitutes. It was a case of "first come, first served." While astronomers were studying their notebooks, those on the alert annexed their rolls, supposing the scientists had overlooked them. The latter were not as absent-minded as one might suppose, however, and a hearty laugh was enjoyed at the expense of the culprit who was caught in the act. Gazing in upon the scene, one would never for a moment have supposed that twenty of the most noted European astronomers were present, for apparently they were taking part in a picnic on a large scale. As one listened to the babel of tongues, in which blended French, English, Spanish, Dutch, and German, it seemed as though every nationality had crowded to the scene, and that pandemonium reigned supreme.

Breakfast at length over, and provision made for the lunch hour, as we could not return to the city until about two o'clock, we proceeded to climb the hill leading to the camp, and on our arrival there we set to work in earnest. The prospect was a dreary one, for the clouds were slowly but surely gathering from every point of the compass,

until the sun was entirely hidden from view, and a shower of rain tended still further to dampen our hopes. To an observer not interested in the vital point at issue, the scene might have appeared highly ludicrous, the woe-begone expression on the faces of the astronomers notwithstanding, for all the telescopes and cameras which had been already focused had to be protected from the falling

THE ASTRONOMERS' CAMP AT BURGOS.

rain. Consequently, caps, handkerchiefs, and umbrellas were pressed into service, so that the astronomical outfit presented a most grotesque aspect.

Every moment our chance of seeing the corona lessened, and only one who has experienced the disappointment can realize what it means to travel thousands of miles and encounter failure. Through occasional gaps in the clouds

we managed to get a glimpse of the sun as the moon gradually passed between it and the earth. When it was a little more than half eclipsed, the clouds drifted over it, hiding it completely from view, and again our hopes went down to zero. Meanwhile, the sky near the western horizon assumed a purplish hue. The northwestern sky was flooded with a vivid orange tint streaked with a few silvery clouds as at dawn. The mountains in the distance were partially shrouded in mist, their summits being dimly visible in the faint light. Plainly could be heard the hum of the voices of the peasants who had approached as near as they dared to our camp, the mounted officers provided by the government keeping away all unwelcome intruders.

As the moment of totality drew near, each one prepared to perform his assigned duty, despite the falling rain and cloudy sky. Nevertheless, the writer could not resist looking in the direction of the approaching shadow, which came like a vast purple cloud enveloping the surrounding landscape and seemed more like a gauze veil of ever thickening folds let down from above, rather than the on-rushing wave so frequently described. Darker and darker grew the scene, the storm clouds overhead assuming a purplish hue, the edges fading from purple into an amber tint of wondrous beauty. A few seconds before totality the rain fell, and then our attention was called to the rainbow colors on a small cloud about five degrees from the sun. It was now half a minute before

totality, and, obedient to orders, despite the fact that the sun still remained hidden behind clouds, we waited, each one ready to perform his task at the eventful moment.

What a farce it all seemed! Astronomers keeping guard at the various telescopes under their charge, assist-

WAITING FOR THE MOMENT OF TOTALITY.
At the left may be seen the mounted officers on guard.

ants ready to handle the photographic plates, others detailed to count aloud the seconds of totality, while to four of us had been assigned the task of making a careful drawing of the corona. Each one of the four was to draw a quadrant, and a fifth member of the party was

quested to make a complete drawing of the corona, the
e drawings to be compared later on and made to form
e material for a composite sketch of the corona.

There we sat, sketching block and white chalk in hand,
ping against hope, and gazing at the place where we
ew the sun was now doubly eclipsed. The silence was

THE APPEARANCE OF THE SKY JUST BEFORE TOTALITY.
The white spot in the center indicates where the sun is hidden.

ly broken by the click-click of the metronome as it
arked off the precious seconds. Five seconds before
tality, four, three; and then the miracle was accom-
ished. As though a hand had drawn aside a veil, the
uds parted, revealing next instant the dark globe of
e moon surrounded by the corona in all its glory. It

extended outward in starlike rays against the darkened sky, while outlined against it, next to the dark rim of the moon, were a few rosy flames like a broken chain of rubies.

Only the voice of the one detailed to count aloud the seconds to the accompaniment of the metronome disturbed the absolute silence which reigned supreme in our tent. An occasional exclamation was quickly suppressed. Swiftly our pencils endeavored to portray those filmy outlines; but as the seconds glided by into minutes, it seemed as though they mocked us with their speed. Thirty precious seconds were wasted, while a small cloud drifted across the sun, though so faint that through it the outline of the corona could be clearly seen. In that brief interval, the writer caught a glimpse of Venus gleaming brightly against a background of purplish blue sky, an oasis amid the vast expanse of cloud. O for the genius of an artist to convey the beauty of that moment, for the color effect on the great masses of cloud, the deep orange tints low down on the horizon, and the wondrous landscape scene around us baffles description!

But inexorable time was passing away, and the cloud which had come so opportunely, as the writer felt, giving a fair excuse to "view the landscape o'er," had drifted on its way, and the work of drawing the corona must be resumed. All too quickly sped the three minutes and forty-five seconds, and as the last ten seconds were doled

out,—as it were,—one at a time, despairing glances were cast at the corona while it gradually faded from view in the first flash of sunlight.

A Photograph of the Composite Drawing of the Corona.
The white spots on the upper edge of the sun indicate prominences.

The writer made the surprising observation that on this occasion the corona did not disappear at once, as it had according to her observation at the previous eclipses of

1896 and 1900, but seemed rather to fade out, its outline remaining visible for nearly fifty seconds after totality. The darkness during totality seemed also much more marked, and it was with some difficulty that the white chalk drawing on the dark blue drawing paper provided could be seen. Probably the clouds added to the darkness usual at such times. At any rate, whatever the cause, the greater gloom, as compared with the writer's previous experiences, was quite noticeable.

As soon as the eclipse was over, a universal sound of cheerfulness pervaded the camp, and the cathedral bells could be heard in the distance ringing a merry peal as on a festival day. East, west, north, and south the news of our success was flashed by cable all over the world, and in Burgos itself rejoicing was general, because the elaborate preparations which the astronomers had made had proved worth while after all.

Notes and drawings were compared, and telescopes and other apparatus carefully packed before the astronomers returned to the city. As we walked slowly down the hill, we met some of the peasants, who kept on gazing at the sun through pieces of smoked glass, as though in hope of another eclipse. Perhaps one of our astronomers was partly responsible for the sale of the smoked glasses, which had been purchased for a penny apiece earlier in the morning. Having a number of broken negatives, he gave them to a native of the town, telling him that they might be

sold to advantage just then. Keen to make a little money, the native showed the negatives duly smoked to an admiring throng, calling their attention to the fact that one of the greatest astronomers in the world had looked through them, and had guaranteed their value. Soon young and old procured some of the magic glasses, and one little girl, too busily intent on observing the sun to notice where she was going, fell full length on the cobblestones and broke her glass to atoms. This seemed to distress her far more than the painful effects of the fall, and she was inconsolable, until a kind-hearted professor who was passing by and had witnessed her distress, provided her with another. Then smiles took the place of tears, and the amateur astronomer happily pursued her study of the sun.

Reports of Other Observations in Spain

Belated astronomers on their way to stations along the pathway of anticipated darkness in Spain had some difficulty, it is inferred, in reaching their destinations. In one instance, late arrivals at the station at Madrid, who were unable to secure accommodation on a train which was going to Sigüenza (a small town within the path of totality), stationed themselves on the tracks in front of the engine, refusing to move until an extra carriage had been added to the train. Vast, bustling, chattering crowds filled each station through which the

train passed, especially in Alcalá and Guadalajara, both of which towns presented a scene of great animation. During the twenty minutes while the train waited at the latter station, it was absolutely besieged by venders of "aqua fria" (cold water), fruits, biscuits, and "melones," at impossible prices; the "melones," as some one expressed it, being "mas altos que el eclipse" (older than the eclipse), and absolutely uneatable.

When the train arrived at Sigüenza, the astronomers had to push their way through the throng of curious peasants and eclipse enthusiasts. Hurriedly they made their way to the city heights, with the object of finding the best place for viewing the eclipse. A ready sale was found for smoked glasses, which vied with "aqua fria" in popularity.

When the time for the eclipse drew nigh, great consternation was felt when the clouds began to drift over the sun, and when raindrops fell, they were said to be the bitter tears shed by the sun at being made captive against its will by the moon. Later on, however, as the clouds passed on, the people, ever enthusiastic, applauded with delight. Soon Venus became visible, which was another signal for applause; but gradually, as the light grew dim, and the time approached for the moment of totality, a hush of awed expectancy settled over the place.

Faces looked ghastly in the waning light, flowers

closed their petals as at night, and the leaves on the trees quivered as though shivering with cold. The birds could be heard twittering as they hastened to their nests, some fluttering down in the streets, allowing the peasants to pick them up in their hands. The chickens, under the impression that it was evening, hastened to their coop, and huddled against each other with ruffled plumage.

During the darkness of totality, sepulchral silence deepened the effect of the gloom, and all gazed in awe at the glorious sight overhead. It was a revelation to the simple peasant folk, and some crossed themselves and muttered a prayer, as though for protection against some unknown evil which had overtaken them. The moment the eclipse was over, and the receding shadow bands danced fantastically over the ground in the wake of the greater shadow, the people shouted with joy and clapped their hands. The eclipse was over, the chilliness of the air was replaced by warmth, and nature assumed her normal aspect. The clouds glowed in hues of gold and purple, while between them against a dark blue background could be seen the bright day star, glorious and triumphant.

A rush was made for the trains, which were filled to overflowing with a bustling, excited crowd, and Sigüenza soon settled down into the usual calm of its everyday existence.[1]

[1] Abstract translated from *El Imparcial* for August 31, 1905.

The astronomical station at Almanzan was occupied by the great French scientist, Camille Flammarion, who was accompanied by his wife; by an expedition from Mexico under the direction of D. Valentin Gama, subdirector of the Mexican National Astronomical Observatory of Tacubaya; and by a third expedition under the direction of Mr. John Miller, professor of astronomy at the Kirkwood Observatory, Bloomington, Indiana.

The results of the observations at this station were most satisfactory. The American astronomers succeeded in obtaining no less than forty photographs of the different phases of the eclipse, the corona, and the coronal spectrum.

Eclipse as Seen from the S.S. "Ortona" in Spanish Waters

The following observations were made by Mr. S. L. Walkden, on the Orient steamer *Ortona*, situated on the central line of the eclipse in the Mediterranean near the Spanish coast. He saw the rainbow colors visible on a small cloud near the sun (already referred to by the writer) about a minute before totality. Although the approaching shadow was looked for, it was not seen; but the shadow bands were observed on deck at the end of totality. They "rippled" along a little faster than could be easily followed by the eye, and were parallel to the strip of the sun after totality, as they traveled in the direction of the shadow. They resembled dark strips

about 6 to 8 inches wide, separated by a distance of about 18 inches.

A minute before totality, Venus could be seen, and Regulus, the brightest star in the constellation Leo, became visible as soon as totality was complete. Mercury was looked for very carefully, but was not caught after about 10 to 15 minutes' search. The corona was very fine and full of detail. The coronal streamers seemed to cross, and were distributed all around the sun, one streamer extending to a distance equal to about two sun diameters. The sun flames of a faintly rosy-pink hue were distributed more or less all round the sun, the chief one being at the left-top corner.

"The lightness of the eclipse was very marked, and time by the watch was always plainly visible. The sky illumination was greatest near the horizon, presenting a yellow glow (like sunset) in points opposite to the sun (about north point). Coast lights were visible a few miles away, and one hill to the north appeared as if perforated, with the sky showing through. This was observed by one other passenger. Venus remained visible nearly five minutes after the end of totality."[1]

Eclipse as Seen from the S.S. "Arcadia" in Spanish Waters

Several attempts were made by members of the British Astronomical Association to arrange an expedition by

[1] Abstract from *Nature* for September 7, 1905.

sea, resulting in failure, until it was found that the P. and O. mail steamer *Arcadia*, leaving Tilbury on August 25, was due to cross the central line of the eclipse on the very day and almost at the very hour of totality. Negotiations were entered into with that company with the view of arranging that the ship should heave to for two or three hours to enable passengers to have a leisurely view of the eclipse. So soon as this decision was reached, it was communicated to the members of the British Astronomical Association and others, who had desired to see the eclipse without making a land journey across France and Spain during the hot days of August. The "station" taken by the ship was only a short distance from the Colombretes Islands, off the coast of Spain.

The *Arcadia* party, under the direction of Mr. G. F. Chambers, F.R.A.S., arranged a programme including observations of the shadow bands, solar flames, and "Baily's Beads,"[1] and making sketches of the corona. These were made with white chalk on blue paper, and a comparison of drawings showed a general agreement as to the outline of the corona being very compact. It was also decided that the corona was very bright, but had no

[1] Baily's Beads are supposed to be produced by irregularities upon the surface of the moon at its edge or limb, the lunar mountains projected against the bright solar crescent causing divisions in its light. They have been described as "golden balls resembling a string of brilliants, which appear for a few seconds before totality on the edge of the moon, and suddenly disappear like drops of water drying up under a hot sun."

definite color other than a silvery hue. There was only one conspicuous ray stretching out from the corona, together with four or five minor rays, none of them very noticeable. "Baily's Beads" were observed by some, but not by all who looked for them especially. The solar flames were much paler than usual, while the elusive shadow bands were seen, though not as very conspicuous objects. A very successful observation of the eclipse shadow was obtained by Mr. Bacon, first officer of the *Arcadia*. He was hauled up in a basket to the masthead, and there saw the shadow of the moon both coming up and going off. This double observation is rarely made, though often attempted. Preparations were made to note the stars which were visible during totality, but the clouds spoiled the effort, and only Venus and Regulus (Alpha Leonis) were visible.

The extreme blackness of the moon in contrast with the corona and with the sky attracted considerable attention, and some of the observers were fortunate in seeing the whole contour of the moon projected on the sky, immediately after the first contact. The breeze, which generally springs up at the time of totality, appeared as usual, with the novel and interesting addition made to the statement that, according to the testimony of one of the ship's officers, the wind suddenly veered through eight points of the compass. The ever changing crescent of light was observed at various stages of the eclipse,

projected on to the deck of the *Arcadia* through the eyelet holes of the canvas awnings.[1]

Eclipse Observations at Palma

At Palma, Majorca, the expedition from the Solar Physics Observatory, South Kensington, London, under the direction of Sir Norman Lockyer, and assisted by the officers and crew of H.M.S. *Venus*, proved unsuccessful, for as the moment of totality arrived dense clouds came up and hid the sun. Sir Norman Lockyer had originally intended to make his observations of the eclipse at a station near Philippeville in Algeria, but for some reason was not permitted to do so by the government. This was especially unfortunate, as clear skies prevailed in this region, and success would have been assured.

Eclipse Observations at North African Stations

Most encouraging reports were received from the observers at the North African stations. Mr. Newall (of the Royal Astronomical Society), at Guelma, was singularly fortunate, having superb weather conditions and obtaining most successful results. He observed a brilliant corona of the "maximum" type, having remarkably long streamers — one of which extended toward Mercury for

[1] Abstract from the *Times Weekly Edition*, September 2, 1905.

more than three degrees — and unusually dark rays. Splendid prominences were also observed by him.[1]

The American expedition, under the direction of Rear Admiral Chester, also succeeded in obtaining splendid photographs of the corona and spectrum, and by a special process made sketches of the solar flames. These flames were observed at the edge of the sun at the beginning and the end of the period of totality. Baily's Beads also were seen. The temperature fell five degrees during totality.

At Sfax (Tunis) various astronomical missions had installed their instruments, preparatory to observing the eclipse. The most important expedition was that in charge of Sir William Christie, the Astronomer Royal.

On the day of the eclipse the city was gayly decorated with flags, and presented the appearance usual on festive occasions. During the whole of the first part of the eclipse, clouds were continually passing over the sun, but during the period of totality they did not, fortunately, interfere with the observations of the corona. Later on, these observations proved to be entirely satisfactory, and many fine photographs of the corona were obtained.

Although the natives of Sfax had been warned beforehand as to what would happen, yet they were frightened at the actual moment of totality, and fled from the European town to the Arab quarters. A number of women banged violently on various utensils in order to

[1] *Nature*, September 7, 1905.

exorcise the evil spirits supposed to be devouring the sun, and the mosques were filled with praying Mussulmans, who shouted with joy when they were told that the sun had reappeared.

At Tripoli, Professor Todd of Amherst College Observatory, Mr. Liberd of Paris, and Professor Millosevitch of Rome were favored with a clear sky. Professor Todd secured some two hundred and fifty photographs of the corona with his automatic coronograph. Very good observations of the shadow bands were also made at this station.

The following is a brief extract from a charming article contributed by Mabel Loomis Todd to the *Nation*: —

The Day of the Eclipse

"Tripoli, Barbary, August 30.

"The day for which we had prepared so faithfully dawned, like all its predecessors after our arrival at Tripoli, in entire clearness. Over the white roofs and beyond the minarets, at four o'clock, the eastern sky flushed faintly, only enough to enhance the glory of Orion and Sirius, of Jupiter and splendid Venus. Growing constantly yellower, the stars faded into it; and by the time the flocks of goats with their tiny, tinkling bells, the slow camels, the overladen donkeys, began to enliven the plaster cañons of streets far below, the sun arose in penetrating brilliance, all unaware of the great event the new day

would bring. But somewhere in sky depths, invisible, lurked the moon in waiting. Higher rose the sun; the moon followed, unseen, but potent. The breeze dropped, and intense heat began. By eleven o'clock the palm groves were mistily yellow, and the desert shimmered in haze.

"By noon the yellow sand haze had risen higher, and the unpleasant possibility of its actually staining the deep blue of the sky at eclipse time, and confusing coronal streamers began to assume larger proportions. In a few moments, however, a gentle ripple turned the pale sea dark blue, the flags which had blown discouragingly outward from the south now hung limply for an instant, and then fluttered manfully forth in the opposite direction. In an incredibly short time the north breeze had cleared the air of sand; once more the palms stood forth distinctly, the horizon retreated.

"Preparations not only for the special photographic work had been made, but arrangements for amateur help in various lines promised much assistance in observing the minor phenomena; and, just before first contact, still another rehearsal of every one concerned was held on the terrace. Plumb lines to assist the artists in drawing the corona had been set up, and a high disk, planned to shut off the intense brightness of the inner corona, and perhaps serve to bring into prominence whatever long, outer streamers there might be, was mounted on the flag-

pole. Small telescopes for drawing fine detail, shadow-band indicators — each was in its place, with a volunteer observer in attendance. The programme ran through smoothly, and at 1.43 the first contact was announced. Very quickly an appreciable piece of the sun's disk was bitten out, the partial phase well on.

"Still duller grew the day, and murmurs began to arise from all the great expanse of roofs, thickly crowded with expectant watchers. Here and there a dome or clustering domes or courtyard foliage emerging broke the even whiteness, now a pale gray. About ten minutes before totality, wavering shadow bands swept across the white roofs in tiny, parallel lines, and the observers, stationed in their especial position, made careful note of direction, width, speed, and all the points most useful for sometime reading the riddle of these elusive appearances. As the crescent grew narrower, I looked particularly for Baily's Beads, but saw none. Upon some of the photographs, however, taken at this time, they are distinctly visible. Fifteen or twenty seconds before totality the corona appeared, on the side farthest away from the disappearing brightness, spreading gradually around until it almost met the actual sunlight. Another second, and totality was announced. Time was marked on an old Arabic bell every fifteen seconds. Eager pencils flew, photographers hurried, spectators applauded, as the soft white corona grew in the purple gray sky, and cast its

pale light over dome and minaret, sea and sand. And inside the big camera dark room, patient hands kept guard over mechanisms which pursued their steady way unmoved by outer glories, piling up the flexible plate chains, each separate holder contributing its record as the time moved on.

"Evenly expanded all around, this corona showed a few longer streamers in extension, and two small scarlet protuberances appeared. The detail in coronal filaments was very beautiful and complex. But the inexorable bell kept up its discouraging tally of the flying moments. Soon a tiny speck of true sunlight reappeared, and totality was over. The corona, however, continued to be visible for nearly fifty seconds."

The Partial Eclipse as Seen in America

At the Harvard Observatory no view whatever of the eclipse could be had, although arrangements had been made to take some photographs, and a special instrument set up to determine the exact time at the beginning and at the end of the eclipse.

The astronomers at Cornell University Observatory at Ithaca were also unable to make any observations because of clouds, and the same conditions prevailed at Montreal and Toronto.

Officers of the U. S. Naval Observatory at Washington

reported that for the greater part of the duration of the eclipse the sun was obscured by clouds. In New York City, the eclipse was a great disappointment, for it was so completely eclipsed by clouds that no observations were possible. Numbers of scientists, amateur and otherwise, had made elaborate preparations for studying the phenomenon.

Future Eclipses

The next eclipse takes place on January 14, 1907, and will be visible in Russia and Persia. Perchance by that time eclipse expeditions will no longer be necessary in our study of the solar corona. In this connection, Professor C. A. Young of Princeton drew the writer's attention to an article in *Nature* for April 6, 1905, entitled, "Photograph of the Corona without a Total Eclipse." The article states that according to a note communicated to the French Academy of Sciences, and in the opinion of M. J. Janssen (the greatest authority on solar physics), M. A. Hansky has succeeded in photographing the corona of the uneclipsed sun. The photographs were taken with a 12-inch telescope in the exceptionally transparent atmosphere which is to be found at the observatory situated on the summit of Mont Blanc.

In presenting the communication, M. Janssen, to whom M. Hansky acknowledges his obligations for assistance and advice, stated that "the photographs actually show

the solar corona with an intensity and a perfection known only on the photographs obtained during total eclipses." (*Comptes Rendus*, No. 12.)

This discovery bids fair to revolutionize our knowledge of the mysterious corona, and when its secrets are revealed, we shall then, by our more intimate knowledge of the sun, become better acquainted with the stars which people the depths of space.

Approach of the Moon's Shadow in a Total Eclipse

Probably one of the most startling effects just before the sun's light is entirely hidden from view is caused by the swift onrush of the moon's shadow. Often it can be seen approaching like a mighty wave, spreading over the earth with frightful velocity. "Swift as imagination, silent as doom," as Mrs. Todd expresses it, in her fascinating little volume on "Total Eclipses of the Sun." "The immensity of nature never comes quite so near to us as then, and strong must be the nerves not to quiver as this blue-black shadow rushes upon the spectator with incredible speed. A vast palpable presence seems overwhelming the world."

An observer who had the opportunity of witnessing the approach of the shadow from the Superga, at Turin, thus describes his sensations: "I perceived," he says, "in the southwest, a black shadow like that of a storm about to

break, which obscured the Alps. It was the lunar shadow coming toward us." He speaks also of the "stupefaction" caused by the spectacle. "I confess," he continues, "it was the most terrifying sight I ever saw. As always happens in the case of sudden, silent, unexpected movements, the spectator confounds real and relative motion. I felt almost giddy for a moment, as though the massive building under me bowed on the side of the coming eclipse."

Another witness, who had been looking at some bright clouds just before, says: "The bright cloud I saw distinctly, put out like a candle. The rapidity of the shadow and its intensity produced a feeling that something material was sweeping over the earth at a speed perfectly frightful. I involuntarily listened for the rushing noise of a mighty wind."[1]

Search for an Intra-Mercurial Planet

Traveling between Mercury (the nearest solar planet) and the sun, there is supposed to be a little, long-looked-for planet. As many myths have been told concerning it as have been told about Vulcan, the god of legendary fame after whom it is named. The fact that the part of its path where Mercury is nearest to the sun had slightly shifted from its calculated line gave rise to the theory that a possible hitherto unknown planet might be the cause of the disturbance.

[1] S. P. Langley, "The New Astronomy," p. 39.

On March 26, 1859, the theory as to the existence of such a planet was seemingly confirmed. The observation was made by Dr. Lescarbault, a country physician living some eighty miles from Paris. He announced that he had actually seen this planet as a spot, quite round and black, passing across the face of the sun nine months before.

When the news of Lescarbault's discovery first reached Leverrier, a French astronomer, who firmly believed in the existence of Vulcan, the latter expressed surprise that the observation had not been made sooner. He did not consider the delay sufficiently justified by the statement that Lescarbault was waiting to see the spot again. He therefore set out for Orgères, the home of Lescarbault, and an amusing account of the meeting is given by Abbé Moigno:—

"One should have seen M. Lescarbault," says the Abbé, "so small, so simple, so modest, and so timid, in order to understand the emotion with which he was seized, when Leverrier from his great height and with that blunt intonation which he can command, thus addressed him: 'It is then you, sir, who pretend to have observed the intra-Mercurial planet, and who has committed the grave offense of keeping your observation secret for nine months. I warn you that I have come here with the intention of doing justice to your pretensions, and of demonstrating that you have been either dishonest or deceived. Tell me, then, unequivocally, what you have seen.'

"This singular address did not bring the interview to an end, as one might have expected. The lamb, as the Abbé termed the Doctor, trembled, it is true, but bravely stammered through a statement of what he had seen. He explained how he had timed the passage of the black spot.

"'Where is your chronometer?' Leverrier asked severely.

"'It is this watch, the faithful companion of my professional journeys,' answered the Doctor, proudly.

"'What! with that old watch showing only minutes, dare you talk of estimating seconds?' thundered the irate astronomer. 'My suspicions are only too well confirmed.'

"'Pardon me,' remarked the Doctor, meekly; 'but I have a pendulum which beats seconds.'

"'Show it to me!' shouted Leverrier, scarcely able to control his feeling of wrath at the Doctor's seeming attempt at imposition.

"The Doctor brought down a silk thread to which an ivory ball was attached. He fixed the upper end to a nail, drew the ball a little from the vertical, counted the number of oscillations, and showed that his pendulum beat seconds. He also explained how his profession required him to feel pulses and count pulsations, so that he had no difficulty in mentally keeping records of successive seconds. He then showed the telescope with which the observations had been made, the record of the observation

on a piece of paper which served as a marker in a French nautical almanac, and the rough attempts he had made in calculating the planet's distance from the sun on a rough board in his workshop.

"'For,' said he, naïvely, 'I am a joiner, as well as an astronomer.'"

Leverrier was satisfied with the explanation, and believed that a new planet traveling between Mercury and the sun had really been discovered. With a grace and dignity full of kindness, forming a marked contrast to his previous discourtesy, he congratulated Lescarbault on the important discovery he had made. At the request of Leverrier, the decoration of the Legion of Honor was conferred on Lescarbault. The name of Vulcan was assigned to the new planet. According to Leverrier, its apparent diameter was estimated at about 2500 miles.

Nothing more was heard of the planet until August, 1876, when astronomers learned that Herr Weber, an observer of considerable skill, stationed at Pecheli in China, had seen a small round spot on the sun, looking very much as a small planet might be expected to look. Imagine his surprise, on turning his telescope toward the sun a few hours later, at finding that the planet had vanished. He forwarded the news of his observation to Europe, and Leverrier was delighted, while Abbé Moigno, who had given Vulcan its name, congratulated Lescarbault on the return of the shy little wanderer.

Lescarbault, however, who had never forgiven the Germans for destroying his observatory and library during the invasion of France in 1870, did not welcome the news that a German astronomer had been the successful observer. It was doubtless, therefore, with some degree of satisfaction that he heard, according to a later report, that certain observations made at the Madrid Observatory, where a careful watch is kept on the sun, and that a photograph taken at the Greenwich Observatory, proved beyond a doubt that the so-called planet was an ordinary, every-day sun spot, not even quite round, and disappearing at the identical time announced by Weber.

Meanwhile, Leverrier's faith in Vulcan remained unshaken, and he came to the conclusion that the planet would cross the sun's surface on or about March 22, 1876. He circulated a dispatch among his friends asking them to be on the watch on that date. Sir George Airy, President of the Royal Astronomical Society, sent telegrams to India, to Australia, and to New Zealand, requesting that observations might be made every two hours. Meanwhile, Leverrier wrote to observers in Santiago de Chile and elsewhere in America and Europe, making the same request. The observations were made and many photographs of the sun were taken, but Vulcan still remained conspicuous by its absence.[1]

During the total eclipse of the sun which occurred in

[1] See "Myths and Marvels of Astronomy," by R. A. Proctor.

1878, Professor Watson of this country announced that he had seen two starlike objects near the sun, but that they were probably the two stars, Theka and Zeka, in the constellation Cancer. Dr. Swift also announced that he had seen two bright stars, but that they were in a different part of the sky. His observations have never been explained.

Probable Discovery of Vulcan

A photographic search for this hypothetical planet was made during the eclipse of 1905. As a result, "it would not be surprising if the world learned soon that Professor Hussey of the Lick Observatory has achieved the distinction, with his battery telescope, of discovering the much-debated new planet between Mercury and the sun."[1] If this proves to be the case, then a new world has been added to the stately retinue of planets which circle around the sun.

Taking it for granted that planet Vulcan does actually exist, it is interesting to note the strange conditions which must prevail on its surface, as compared with our own planet earth. Who knows but that the sun, which shines upon it, ministers to the needs of countless living beings upon its surface? Yet such beings could not be constituted as we are and endure the enormous supply of

[1] *New York Herald*, September 21, 1905.

heat and light which must undoubtedly be squandered on this neighbor planet to the sun.

Even on Mercury the heat must be intolerable, the sun blazing in the Mercurian skies with a disk four and a half times larger than that which he presents to the observer on earth. What, then, must be the size of the sun as seen from the new planet which is now believed to circle between Mercury and the sun? All vegetation must be parched beneath the scorching sun rays, the oceans evaporating as steam. Mortals possessing eyes like ours would be blinded by the dazzling glare of sunlight, and must welcome with delight the hours of night and darkness.

But, alas! on Vulcan the same state of affairs regarding night and day may prevail that distinguishes the planets Mercury and Venus from the other planets in the solar system. That is, there may be perpetual daylight on one side of the planet and perpetual night on the other. Fancy the consternation that would be caused should constant day or night prevail here. Supposing the western hemisphere to be the side ever illumined by the bright Day-star; then, when weary of the sunlight, we must cross the broad Atlantic to the eastern hemisphere in search of the restful darkness of an endless night. Even so, imagine the intense cold which must prevail in a region untouched by the sun's rays, and the scene of desolation that would greet us. The prospect is not inviting, whichever way we choose to regard it; but it

makes us realize more fully how peculiarly our own planet is adapted for life as we know it here.

On the other hand, the difference in temperature and climate which must exist on Vulcan as compared with our planet does not of necessity prove that the planet is an unsuitable abode for living creatures. Though every living creature on this earth would at once perish if removed to a planet so near the sun, yet we cannot thence conclude that the planet is uninhabited at present, or that in the course of time life may not exist upon its surface.

Though the whole mass of Vulcan may now be heated to a degree a thousand fold more intense than that of the fiercest heat we know of, yet in the ages to come when the heat of the sun itself has decreased, as it undoubtedly will, and Vulcan will have correspondingly cooled off, then life may become possible upon its surface. At that remote period the earth will probably be at its last gasp, and on the verge of extinction.

We can then imagine a Vulcanian professor of astronomy turning his telescope in the direction of our planet, and calling the attention of his pupils to the fact that the earth has become a burned-out cinder like the moon, but may once have been the abode of life, judging from the life history of their own planet. He might also add that the same fate that has befallen the earth must at some time overtake planet Vulcan, for in the ordinary course of events it, too, must eventually grow old and die.

CHAPTER IV

THE PLANETS

A CERTAIN number of planets, or "wanderers," as they were called in olden times, revolve around the sun in oval paths that are nearly circular. In the order of their distance from the sun, these planets are Mercury, Venus, the Earth, Mars, and Jupiter, Saturn, Uranus, and Neptune. Between Mars and Jupiter are the asteroids, a group of several hundred small bodies.

Planets resemble stars so closely that they are often mistaken for them, but in reality they differ greatly. *A star is a mass of glowing vapor and shines with its own light, but a planet is a dark globe resembling the earth and shines only by means of light reflected from the sun.* If the light of the sun were withdrawn, the planets would become invisible. A star, on account of its enormous distance from the earth, is visible only as a small point of light; while a planet, being comparatively near, has the appearance of a clearly defined, round disk.

If we observe carefully the movements of the planets during the course of a year, we shall find that they are all moving with different velocities in the pathway marked

out by the twelve constellations of the zodiac, or imaginary belt of stars in the heavens. The fact that the planets change their places with regard to the stars in their neigh-

borhood proves that they are truly "wanderers" among the stars. The latter, on the contrary, are at such an enormous distance from the earth, that if the astronomers of old were to return to the scene of their labors, they

would find the relative position of the stars, with regard to each other, exactly the same as in ages gone by.

The stars may be compared with steamers seen on the distant horizon, apparently motionless owing to their great distance, but in reality plowing their way through the waves as fast as steam can take them. The planets, on the other hand, are like the small boats near the shore, whose movements can be easily followed, as they approach, recede, and finally disappear.

Size of the Solar System

When compared with any terrestrial standard of distance, the size of the solar system is immeasurably vast. As a practical illustration, Sir John Herschel gives the following interesting comparisons: —

"Choose any well-levelled field. On it place a globe two feet in diameter. This will represent the sun. Mercury to be in proportion will not be any larger than a grain of mustard seed on the circumference of a circle 164 feet in diameter for its orbit; Venus will be represented by a pea on a circle 284 feet in diameter; the earth, also a pea, on a circle of 430 feet; Mars, a rather large pin's head, on a circle of 654 feet; the asteroids, grains of sand on orbits having a diameter of 1000 to 1200 feet; Jupiter, a moderate-sized orange on a circle nearly half a mile across; Saturn, a small orange on a circle of four fifths of a mile;

Uranus, a full-sized cherry on a circle more than a mile in diameter, and finally Neptune, a good-sized plum on a circle about two and one half miles in diameter." We may add that on this scale the nearest star would be on the opposite side of the earth, 8000 miles away.

Mercury, a Fiery World

THE FLEETEST OF THE GODS. SIGN ☿, HIS WAND

When we see this planet just after sunset as a bright star sparkling near the western horizon, it is an evening star. Some days afterward, when we see the same planet just before sunrise in the eastern sky, it is a morning star. Thus the planet appears to swing slowly to and fro, from one side of the sun to the other. Astronomers of olden times supposed there were two stars, and named the morning star Apollo, the god of day. To the evening star they gave the name of Mercury, for Mercury was the god of thieves, and the planet Mercury steals more light and heat from the sun than any other planet.

The average amount of heat received by Mercury is about seven times the amount received by the earth (a temperature sufficient to turn water into steam), but the amount of heat received when the planet is at its nearest to the sun is two and a quarter times greater than when the planet is at its greatest distance. For this reason, there must be at least two seasons in its year.

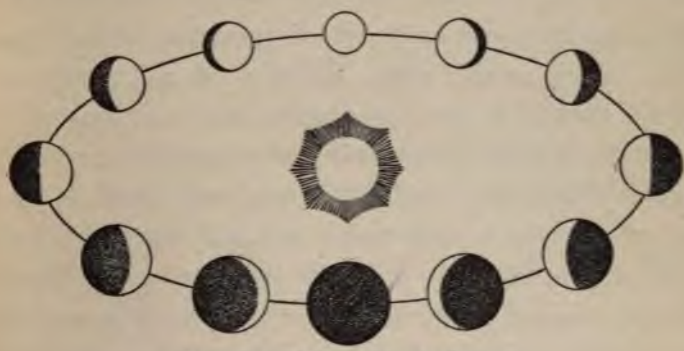
As we have stated before, Mercury is the nearest planet to the sun. *Its mean distance from the sun is about* 36,000,000 *miles.* If a railroad track could be made reaching from Mercury to the sun, a train going at the rate of a mile a minute would require sixty-eight and a half years to reach its destination. Mercury moves with great rapidity, its speed varying from 23 to 36 miles a second. At the latter rate of speed, a steamer could cross the Atlantic Ocean in less than two minutes!

The year on Mercury is a period of only eighty-eight days, or not quite three of our months. In 1889, Schiaparelli, the famous Milanese astronomer, announced that he had discovered certain markings upon the planet, and that they showed that the planet always keeps the same face turned toward the sun, just as the moon does toward the earth. Therefore, there must be perpetual day on one side of the planet, and perpetual night on the other. The sunny side is constantly exposed to the fierce glare of sunlight. "Mercurian oceans, could they ever have been formed, would long ago have been boiled off from the hot side, and condensed into thick-ribbed ice on the cold side."[1] On the dark side of the planet, night must reign supreme. For the inhabitants of Mercury, if such there are: —

> "There is no light in earth or heaven,
> But the cold light of stars."

[1] A. M. Clerke, "Astronomy," p. 277.

Seen through the telescope, Mercury looks like a little moon, showing phases similar to those of our moon. When the planet is between us and the sun, the dark side is toward us, since the sun is shining on the side turned away from us. When the illuminated surface is turned in our direction, the planet appears successively as crescent-



PHASES OF MERCURY AND VENUS

shaped, half moon, gibbous (a little more than half), and again crescent, until its dark side is between us and the sun.

Mercury is a smaller planet than the earth, for *its diameter is only about* 3000 *miles*, while that of the earth is nearly 8000 miles. Its mass is less than that of any other planet, the asteroids excepted, and the force of gravity upon its surface is about one quarter what it is upon the earth. A man who here weighs 150 pounds would weigh but 37½ pounds on Mercury.

Venus, the Evening Star

THE QUEEN OF BEAUTY. SIGN ♀, A LOOKING-GLASS

"Now glows the firmament
With living sapphires; Hesperus, that leads
The starry host, rides brightest."

—"Paradise Lost."

Next to Mercury, in point of position, is the planet Venus, which is the most brilliant of all the planets. Like Mercury, it is seen for a time as a morning star in the eastern sky presenting all the phases (or changes) of the moon; then it is lost in the sun's rays, and reappears again in the west as an evening star. When visible before sunrise, it was formerly called Phosphorus, or the Morning Star, and when it shone in the evening after sunset, Hesperus, Vesper, or the Evening Star. There are times when the planet is so bright that it casts a shadow at night, and it may be seen with the unaided eye in full daylight.

"Arago relates that Bonaparte upon repairing to the Luxembourg, when the Directory was about to give him a *fête*, was much surprised at seeing the multitude paying more attention to the heavens above the palace than to him or his brilliant staff. Upon inquiring, he learned that these curious persons were observing with astonishment a star which they supposed to be that of the Conqueror of Italy. The emperor himself was not indifferent when his

piercing eye caught the clear luster of Venus smiling upon him at midday."

The mean distance of Venus from the sun is 67,200,000 *miles.* A period of 225 days, or seven months and a half, is required for the planet to complete its yearly trip, although it travels at the rate of 22 miles a second. Being nearer to the sun than we are, Venus receives almost twice as much light and heat, but less than one third as much as Mercury. *The diameter of the planet is* 7700 *miles* (nearly equal to that of the earth), and in magnitude might be termed the earth's twin sister.

Like Mercury and the moon, Venus always keeps the same face turned to the sun, with the same result, *i.e.* perpetual day on one side of the planet and perpetual night on the other. The kind of weather that prevails on Venus almost baffles description. The appearance of the evening star betokens peace and serenity; in reality, however, the surface of this planet is a scene of the utmost turmoil and confusion. There are probably violent windstorms raging unceasingly between the half of the planet upon which the sun never rises and that upon which the sun never sets. The ocean of air surrounding the planet must be agitated to its very depths, while great masses of cloud, torn in shreds by fierce cyclonic storms, are driven hither and thither at a terrific rate of speed. The most intense cold doubtless prevails on the side of the planet untouched by the sun's rays, while a torrid heat parches and con-

sumes all things on the sunlit side. Under such conditions, the planet seems ill-fitted to be the abode of life.

At the regions in Venus corresponding to the polar regions on earth, bright spots have been occasionally observed, which may perhaps be "ice caps." The surface of the planet is so bright that it is difficult to study it with a telescope, but certain dark shadings which have been seen may possibly be continents and oceans faintly outlined, or more likely masses of cloud floating in the atmosphere. Until recently, it was thought that the density of the atmosphere of Venus was greater than that of our planet, but observations made in 1898 tend to show that, on the contrary, the atmosphere is somewhat rarer than that of the earth.

Certain peculiar notches seen on the edge of the planet during its crescent phase have been referred to as mountains by some observers. One astronomer went so far as to give them the extravagant height of twenty miles, but the evidence is not sufficient to warrant our accepting such a conclusion.

Occasionally Venus passes between the earth and the sun, giving us what is called a "transit of Venus." She is then visible to the unaided eye as a black spot on the sun's disk, crossing it from east to west. The last transit occurred December 6, 1882, and the next is not due until June 8, 2004. The transit of 1882 was visible in the United States.

The Earth

SIGN ⊕, A CIRCLE WITH EQUATOR AND MERIDIAN

"Look downward on that globe whose hither side
With light from hence, though but reflected, shines:
That place is earth, the seat of man; that light
His day, which else, as th' other hemisphere,
Night would invade."

—MILTON.

Looking backward through the vistas of time, when the earth was in the infancy of its career as a planet, we must imagine it

"A dark
Illimitable ocean, without bounds,
Without dimension, where length, breadth, and height,
And time and place are lost, where eldest night,
And Chaos, ancestors of Nature, hold
Eternal anarchy, amidst the noise
Of endless wars, and by confusion stand,
For hot, cold, moist, and dry, four champions fierce
Strive here for mastery, and to battle bring
Their embryon atoms."

Over this ocean of fire drifted the air, dense with moisture and acid vapor, until, in the course of time, the surface of the earth cooled and a thin crust formed. This crust was soon covered with rich verdure, and the earth then became a scene of wondrous beauty, with its carpet of tropical plants and flowers amid forests of graceful ferns.

A terrible catastrophe then took place, for icebergs from the Arctic regions came floating slowly along the valleys,


ARCTIC
OCEAN
ANTARCTIC
OCEAN
INDIAN
OCEAN
ATLANTIC
OCEAN
PACIFIC
OCEAN

have his doubts as to whether such a planet could be an inhabited world. On the contrary, these oceans and seas prove that the earth is in the very heyday of its youth. As it approaches old age, the seas and oceans will gradually grow less, though so slowly that centuries must pass away before any visible change takes place. "Now, let us imagine that the rate at which the water in our seas and oceans is withdrawn into the interior of the earth is so slow, that in a single year the sea level is reduced by an amount equal to about the thickness of a sheet of paper. Then in a hundred years the depth of the sea would be diminished only a single inch. At this rate, in about 6,400,000 years the sea level would be reduced a full mile, and in 60,000,000 years every trace of water would have disappeared from the surface of the earth." [1]

With the vanishing of all water would vanish also even the air that we breathe, so that life would no longer be possible on our planet. Fortunately for us, however, the earth is surrounded by a great blanket of air, hundreds of miles in depth. "Were there no atmosphere, the evening sun would in a moment plunge the earth in darkness, but the air keeps in her hand a sheaf of rays, and lets them slip slowly through her fingers, so that the evening shadows gather by degrees, and the flowers have time to bow their heads, and each creature to find a place of rest to nestle and repose. In the morning, the dazzling sun

[1] R. A. Proctor, "Mysteries of Time and Space," p. 65.

would at once burst from the shades of night and blaze above the horizon, but the air watches for its coming, and sends first one little ray and then another to announce its approach, and by and by a handful. Thus, he gently draws aside the curtain of night, and slowly lets the light fall on the face of the sleeping earth, till her eyelids open, and,

like man, she goes forth again to her labor till the evening."

The earth in its journey through space is flying around the sun with a velocity of about eighteen and a half miles a second, that is, about seventy-five times as swiftly as an ordinary cannon ball. Were it not for the invisible power of gravitation, which makes the sun resemble a gigantic magnet

keeping the planets ever circling around it, the earth would wander aimlessly in space. As it is, the sun's attractive force upon the earth is equal to the breaking strain of a steel rod about three thousand miles in diameter. To replace the sun's attraction, a web of the heaviest telegraph wires would have to cover the whole side of the earth turned toward the sun. These wires would need to be as thick as blades of grass upon a lawn, *nine* wires being required to each square inch.[1]

In a romance entitled "Lumen," Flammarion, the popular French writer on astronomy, draws a weird picture of what would happen if such a catastrophe should take place: —

"If by any cause this earthly planet were one day to fly off from its orbit (path) at a tangent, or rush away into the glacial obscurity of space, all the water on the earth would become solid, and gases turn liquid, while the solids and all human beings would find themselves immediately frozen on the spot. The globe would carry into space the singular panorama of the whole human race immovably congealed in the various attitudes assumed by each individual creature at the moment of the catastrophe. They would have been transformed into millions of statues sunk in a complete lethargy, for the cold would have preserved them. Three or four thousand years later, were the planet to return from its dark and

[1] See C. A. Young, "The Sun," p. 41.

frozen aphelion (greatest distance from the sun) to its brilliant perihelion (when a planet is nearest to the sun), they would all be resuscitated at the age at which they were overtaken by sleep. They would continue what they were doing without any consciousness of having slept a dreamless sleep for many ages. Some might be seen continuing a game, or finishing a phrase whose first words were uttered four thousand years ago. All this is perfectly simple, for time does not in reality exist."

The Moon, a Dead World

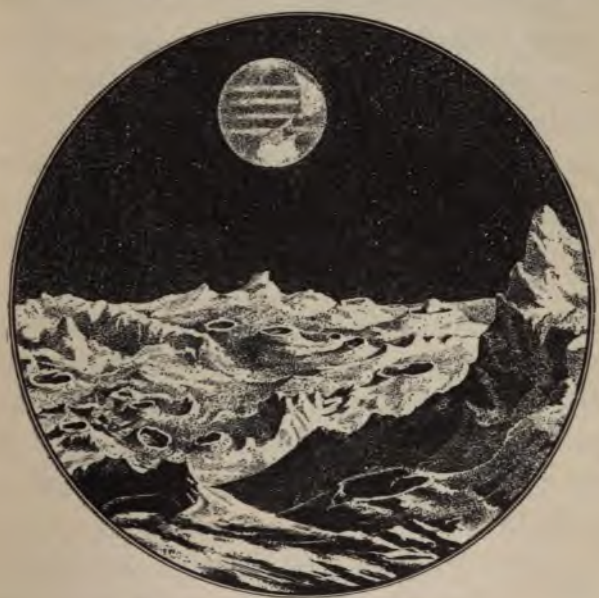
"The Moon, whose orb
Through optic glass the Tuscan artist[1] *views*
At evening, from the top of Fesolé,
Or in Val d'Arno, to describe new lands,
Rivers, or mountains, on her spotty globe." — MILTON.

Circling around the earth is the planet moon, a dead world that has run its course. Could we in some way be transported to this globe, we would find a gloomy and desolate region indeed. Owing to the fact that there is not a drop of water on the moon, nor a blanket of air surrounding it, as in the case of our own planet, life would be impossible on its surface. Not a sign of vegetation would be visible anywhere, — not a tree, a flower, nor even a blade of grass to relieve the dreary monotony of boundless

[1] Milton refers to Galileo's work with the telescope in his study of the surface of the moon. Galileo was a native of Tuscany.

plains, of mountain heights, or of yawning chasms. Speech would be utterly useless, as there is no air to carry the sound of a voice. The silence of death would prevail.

The absence of air must also cause startling effects on the lunar landscape. We should see distant mountains



EARTH AS SEEN FROM THE MOON

sharply outlined against the sky, unsoftened by the soft, misty haze which adds to the beauty of such a scene on our planet. The stars would be always visible in a perfectly cloudless sky, which is always as black as night and

far more resplendent than ours, since there is no atmosphere to dim the luster of the stars; but the blue of our sky each day and the magnificent colors adorning it at sunrise and sunset are there absolutely unknown.

Dense shadows on the moon form a sharp contrast to the light, for there are none of the soft gradations due to the blending effects of atmosphere. For this reason, the moon would be an ideal place for a game at hide and seek. The instant one stepped into the shadow of a lunar mountain, he would become invisible.

The mass of the moon is one eighty-first that of the earth, eighty-one globes as massive as the moon being required to equal our planet in weight. *The attraction of the moon for bodies at its surface is about one sixth that at the surface of the earth.* A man weighing 150 pounds here would weigh but 25 pounds there. The lightness of our bodies in the moon would entirely transform many of our most familiar games. The following unique illustrations are given by Sir Robert S. Ball, in his book entitled "Starland": —

"In cricket, I think the bowling wouldn't be so much affected, but the hits on the moon would be truly terrific. I believe an exceptionally good throw of the cricket ball here is about a hundred yards, but the same man, using the same ball and giving the same run to it, would send the ball six hundred yards on the moon. So, too, every hit would in the lunar game carry the ball to

six times the distance it does here. Football would show a striking development in lunar play; a good kick would not only send the ball over the crossbar, but it would go soaring over the houses, and perhaps drop into the next parish.

"Our own bodies would, of course, participate in the general buoyancy, so that while muscular power remained unabated, we should be almost able to run and jump as if we had on the famous seven-league boots. I have seen an athlete in a circus jump over ten horses placed side by side. The same athlete, making the same effort, would jump over sixty horses on the moon.

"A run with a pack of lunar fox hounds would indeed be a marvelous spectacle. There need be no looking round by timid horsemen to find open roads or easy gaps. The five-barred gate itself would be utterly despised by a huntsman who could easily clear a hayrick. Nor would the farmer be astonished if all the field jumped over his house without disturbing a slate on the roof. It would hardly be worth while taking a serious jump to clear a canal unless there was a road and a railway or so, which could be disposed of at the same time." [1]

In his interesting little book on "Astronomy," Professor Newcomb gives his idea of how the force of gravity on the moon would affect a game of baseball:—

"If a baseball club could fly to the moon and there

[1] R. S. Ball, "Starland," pp. 123, 124.

play a game, the distinction between mass and weight would be very evident. The mass being the same as here, the pitcher would not be able to throw the ball any faster than he can throw it on the earth. The catcher would find the ball striking as heavy a blow in his hands as it does here.

"As the ball would be drawn toward the moon by only one sixth the force that the earth draws it, it would be found to be as light as a rubber ball. It would stay long in the air when batted, and home runs would be made all the time."[1]

The volume of the moon is one forty-ninth that of the earth, so that 49 such bodies rolled into one would be required to equal the volume of the earth. *The diameter of the moon is* 2163 *miles,* only a little more than a quarter that of the earth, and its surface is equal to about one fourteenth of the earth's, or almost equal to the united surface of North and South America. *The distance of the moon from the earth is* 238,840 *miles.* A train going at the rate of a mile a minute on a railroad track reaching from the earth to the moon would require 165 days, 20 hours, 4 minutes.

Mountains on the Moon

In early ages men began to form strange theories regarding the moon. Some philosophers supposed that it was

[1] Simon Newcomb, "Astronomy," p. 85.

made of glass and reflected light like a mirror, and that the dark markings were the reflections of the oceans and continents of our planet. It was only after the invention of the telescope that the truth was actually learned about the condition of the moon's surface.

In 1610, Galileo turned the first telescope ever made in the direction of the moon, whose surface he found, to his great surprise, was sculptured with mountains, valleys, and so-called seas and oceans. He could perceive bright points of light separated by dark spaces from the edge of the crescent moon, and he recognized the fact that these points are the tops of mountains illuminated by sunlight while the surrounding valleys are in darkness.

Those who have watched the sun rising from the top of a lofty mountain know that when the mountain is in the full glory of sunlight, the sides of the mountain are still in shadow, and that the neighboring valleys are plunged in a yet deeper gloom. Then again, when the sun is setting, long before the mountain tops are darkened, the level country around is in twilight shadow, and the obscurity of night has already settled over ravines and passes.

The only difference which Galileo perceived in the phenomenon of sunrise and sunset on the lunar mountains from that observed in a terrestrial mountain scene, was that no half lights were visible, only the bright blaze of sunlight on the mountain tops, and intense blackness in the valleys. This proved the absence of any atmosphere, for the faint

light which illuminates the valleys of a mountainous region, while as yet the mountain tops are in sunlight, comes from the sky, and the light of the sky is due to the existence of an atmosphere.

Since the days of Galileo, we have learned that not only does the moon lack air, but the so-called seas and oceans on its surface are in reality vast plains. At some remote period, life and vegetation may have been possible on the moon and the "plains" may have been actual seas and oceans. But now the surface of the moon is scarred and furrowed with the marks of age. It is not only wrinkled and old, but a dead world. All the beauty the moon may have had in the days of its youth has long since disappeared, and distance alone "lends enchantment to the view." Even its light is borrowed from the sun, and it is this borrowed light that endows the moon with seeming loveliness.

GALILEO.

In height, many of the lunar mountains equal some of the highest mountains on the planet earth. As the sun rises on the moon, the black shadows of the mountains fall ing the moon. ce across the plain below. These shadows

[1] Simon length, and their outlines gradually

creep up the sides of the mountains as the sun approaches the point overhead. When the sun begins to set, the shadows fall in the opposite direction across the plain, until the mountain summits alone are illumined by its rays. It is by means of these shadows, whose lengths are readily determined (with an instrument used for such purposes, known as a micrometer), that it has been possible to estimate the height of the lunar mountains, and the depths of the extinct volcanoes or craters in their vicinity. The best time to observe the shadows creeping over the plain, and the advancing line of lunar sunrise painting the peaks of the mountains with golden hue, is when the moon is crescent shaped. The observation can be made with an ordinary opera glass. The points of light which can be seen apparently separated from the crescent are in reality sunlit mountain peaks, the dark spaces between being valleys concealed by shadows.

The greatest chain of mountains on the moon is known as the Apennines. They extend some 460 miles, and contain a peak 21,000 feet high. The range known as the Alps is an exceedingly steep and lofty chain of mountains rising into separate peaks. One of these peaks, which reaches a height of 14,000 feet, is called Mont Blanc. A valley from three to six miles in width breaks through the Alps in a straight line, extending nearly 83 miles. Many of the deep valleys on the moon may once have been rivers.

From an examination of the maps and photographs which have been made of considerably more than a thousand of these moon valleys, they are said to resemble the

THE LUNAR APENNINES.

cañons of Colorado. Some few run to a distance of 150 miles, and are about a quarter of a mile deep. Their origin is probably volcanic.

Crater Mountains

The same may be said about the crater mountains, which resemble the volcanoes of the earth, but far exceed them in size. When the moon in the infancy of its career was in a molten condition, like that of the earth when the latter was "without form and void," a thin crust probably formed over its surface during the cooling period. Numberless bubbles formed, with ridges surrounding their edges, resembling volcanoes on a gigantic scale. In fact, we have nothing on earth which compares with the great lunar crater Ptolemy, a ringed plain 115 miles in diameter, large enough to inclose an area of nearly 8000 square miles, or about that of the state of Massachusetts.[1]

Perhaps the nearest approach to a lunar ring mountain on earth is an extinct volcanic plain 20 miles in diameter, which is said to exist on the island of Mauritius. Then there are the lunar volcanoes of Kilauea (kē-lou-ā′ä) and Haleakala — the one a fiery, the other a frozen, lake of lava. The craters or volcanoes of Java are also said to bear a resemblance to some of the smaller lunar volcanoes.

Tycho

The most perfect type of a lunar volcano is Tycho (tī′kō), which presents a magnificent scene as the sun rises on it,

[1] S. P. Langley, "The New Astronomy," p. 155.

the rays appearing to radiate in all directions. The enormous cavity in the center of the mountain is 54 miles in width, while its depth is more than three miles below the summit of the ring. Imagine standing on the brink of such a precipice, with its sheer depth of three miles!

Beyond the ring extend streaks or rays, varying from ten to twenty miles in width, and several hundred miles in length. One ray about 2000 miles long reaches as far as the Sea of Serenity, which is a plain in the southwestern region of the moon's surface, while Tycho is in the northeastern part. A large crater named Saussure (sō-sür′), not far from Tycho, lies directly in the line of a ray and appears to intercept it, but at the bottom of the crater, notwithstanding its great depth, the ray from Tycho can be traced. The most conspicuous streaks radiating from Tycho originate outside its walls, and turn aside for neither mountain nor valley. They pass over the roughest regions of the moon's surface, retaining their light undiminished. The rays from Tycho are plainly to be seen at the time of full moon, when the latter's surface is flooded with sunlight. Then the brilliant streaks are visible, like the ridges one sees upon an orange after the rind has been removed. For this reason, in fact, the appearance of the moon at such a time has often been compared to that of a peeled orange.

Copernicus is a lunar crater 56 miles in diameter, with a central cone 24,000 feet in height, and is surrounded by a

ring composed of terraces and distinct heights separated by ravines. The summit of the crater is a narrow ridge rising 11,000 feet (height of Mount Etna) above the plain below.

THE CRATER COPERNICUS.

The interior cliffs resemble those of the great crater of Teneriffe, and are apparently composed of lava. Copernicus comes into sight a day or so after the first quarter,

when it is very brilliant, the edge of the ring sometimes resembling a string of pearls. Tycho, Copernicus, and another famous crater, named Kepler, are among the most famous lunar volcanoes, while nearly 33,000 smaller ones furnish records of a fiery past in the history of the life of the moon.

Changes on the Moon's Surface

Not far from the lunar Alps is a dark and level plain named Plato, sometimes called the "Black Lake." It is surrounded by a ring of mountain peaks rising to a height of seven or eight thousand feet. During July and August of the year 1904, a bright spot suddenly appeared in the "Lake" and soon changed into an oval patch about three miles in diameter. This would seem to indicate that the moon still has life left in it, enough at any rate to cause a volcanic eruption on a gigantic scale.

In the neighborhood of the Sea of Serenity, a minute black spot can now be seen in place of a once wide and deep crater named Linné (lin-nā'). The latter's disappearance was observed by an astronomer named Schmidt in October, 1866. It was a crater fully five and a half miles wide, and very deep. It was, in fact, one of the largest craters within the Sea of Serenity.[1]

[1] R. A. Proctor, "The Moon," p. 194.

Plains

The so-called seas on the moon, which are in reality vast plains bearing a resemblance to the deserts of the earth, are generally of a grayish hue and darker than the surrounding region. The Sea of Serenity, the Sea of Tranquillity, the Crisium Sea, the Bay of Rainbows, the Lake of Dreams, the Ocean of Storms, are some of the fanciful names bestowed upon them by the astronomers of old. These names are still in use, and enable us to identify any part of the visible face of the moon. Owing to the fact that the moon, like Mercury and Venus, always keeps the same face turned in our direction, there is one side we can never see. Consequently all sorts of odd fancies have been suggested about this unseen side.

THE CRISIUM SEA.

"Among the most curious is the ancient belief that the souls of the good who die on earth are transported to that

side of the moon which is turned away from the earth; while the souls of the wicked live on this side in full view of the scene of their evil deeds. The visible side of the moon — with its tremendous craters, its yawning chasms, its frightful contrasts of burning sunshine and Cimmerian darkness, its airless and arid plains exposed to the pitiless cold of open space, and heated, if heated at all, by scorching sunbeams — would certainly appear to be in a proper condition to serve as a purgatory. But we have no reason to think that the other side is any better off in these respects. In fact, the glimpses that we get of it around the corners, so to speak, indicate that the whole round globe of the moon is as ragged, barren, and terrible as that portion of it which is turned to our view." [1]

Lunar Month and Day

While accompanying the earth in its yearly journey around the sun, *the moon revolves about the earth once in about twenty-seven and a third days.* The lunar day is equivalent to four of our weeks, so that there must be twelve lunar days in a year, and somewhat less than three days in each of the four seasons. Daytime, consequently, lasts on the average about two of our weeks, and night lasts equally as long — a singular contrast indeed to the state of affairs on the earth.

[1] Garret P. Serviss, "Astronomy with an Opera Glass," p. 138.

Phases of the Moon

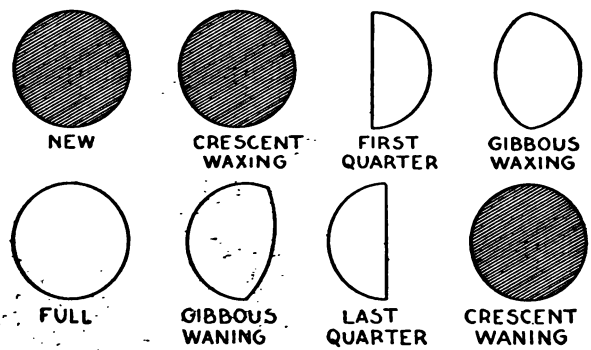
The moon shines with light reflected from the sun; when its dark side is toward us, we cannot see it at all. It is then said to be *new* moon. Two or three days later, a *crescent* of light is visible, the rest of the moon having a faint gray hue. This is when the old moon is said to be in the new moon's arms. Three or four days after the appearance of the crescent, the *half* moon forms, and then as we see more and more of its illuminated surface, the moon is said to be *gibbous*. When the moon is exactly opposite the sun, she presents the same face to the earth and to the sun, and is then called *full moon*. During the rest of her journey, these phases recur in the *reverse order* until we again lose sight of her at *new* moon.

After Barnard.

THE OLD MOON IN THE NEW MOON'S ARMS.

An extremely simple illustration can make these phases clear. Place a lighted lamp on a table, and let it represent the sun. Let your head represent the earth, and standing in front of the lamp, hold out a tennis ball at arm's length. When it is between you and the lamp, the

darkened side is toward you, as in the case of *new* moon. Now turn slowly toward the left, and while turning look at the ball, whose changing appearance will show the changing phases of the moon. As the path of the moon is tilted slightly above the plane of the earth, the sunlight passes over the earth to the moon. Therefore, when the observer has turned round halfway until the ball shows the phase of full moon, the ball must be raised slightly



THE PHASES OF THE MOON.

above the head, so that the light from the lamp can illumine its surface. Otherwise, the observer's head would be in the way, causing a total eclipse, just as there is a total eclipse of the moon when the earth comes between the sun and the moon, and plunges the latter into its shadow.

Eclipse of the Moon

The shadow thrown by the earth tapers down to a point, and this point lies more than 857,000 miles from the earth.

The moon crosses this shadow at a distance of 238,840 miles from the earth, where the shadow is about 5000 miles across. If the *whole* body of the moon passes into the shadow, the eclipse is said to be *total;* if only a *part* of the moon passes into the shadow, the eclipse is said to be *partial.* Even in a total eclipse, however, the moon is not always in total darkness, some light being bent into parts of the earth's shadow by the action of its atmosphere. This light usually gives to the totally eclipsed moon a copper color, or deep brown hue.

The Tides

Just as the attraction of the sun, owing to the great law of gravitation, keeps the earth circling around it, so the earth attracts the moon and keeps the latter in its orbit. If it were not for this great power, the moon would gradually leave the earth altogether. But the moon attracts the earth, as well as the earth the moon, so the two cannot get away from each other. There was a time when the moon formed part of the earth, but the earth was then a soft molten mass spinning round four times as fast as it does now. The speed was so great, apparently, that a part of the molten mass whirled away from the central globe, and formed a small globe circling round the larger. In the course of time, the moon gradually retreated from the earth, although the two continued (as they do to this day) revolving around their common center of gravity. The

distance between the moon and the earth increased until the moon is now thousands of miles from its mother orb.[1]

The power of attraction exerted by the moon on the earth produces a rising and falling motion of the waters of the earth, called *tides*. The sun also helps in producing this effect, but is not as powerful as the moon, which is four hundred times nearer the earth. The portion of the earth near the moon is attracted more strongly than the portion more distant. Consequently, as the water of the ocean is movable, it is stretched out a little from the earth. A similar wave is produced on the other side of the earth, as the moon pulls the earth away from the water, which may be said to be left behind. These waves are called *tidal* waves. When the water is at its highest, it is called *high tide;* at its lowest, it is called *low tide.*

At new and at full moon the sun acts with the moon in causing tides, the highest being *spring tides* and the lowest, *neap tides.* "The difference between ebb and flood neap tide at New York is over three feet, and that of spring tide over five feet. The tidal wave ascends the Hudson River at about the same speed as steamboats; at Albany, it reaches a height of a little over two feet." [2]

[1] A detailed account of the fascinating history of the moon during this period of its career cannot be given here, but the reader is referred to R. S. Ball's book entitled "Time and Tide," and also to the chapter on Tides in his "Story of the Heavens."

[2] J. D. Steele, "New Descriptive Anatomy," p. 150.

CHAPTER V

THE PLANETS (*continued*)

Mars, a Miniature Earth

THE GOD OF WAR. SIGN ♂, SHIELD AND SPEAR

"Yon world — the ancient warrior's star
That shines with ruddy beam afar,
And next to earth his annual way
Describes around the orb of day: —
His face with telescope when scanned
The semblance shows of sea and land,
While mists of ever changing mien
And sparkling arctic snows are seen.
Nor longer "moonless": — worldlets twain
Revolve obedient 'neath his reign."

— ARTHUR MEE, F.R.A.S.

PASSING outward in our survey of the solar system, we come to planet Mars, our next-door neighbor in space. This planet is smaller than the earth, for *it is only* 4300 *miles in diameter*. Its volume is one seventh that of the earth, so that if the substance in the earth were rolled into seven balls, each ball would equal the volume of Mars. Its mass is a little less than one ninth of the earth's mass. Could Mars and the earth be weighed in a gigantic pair

of scales, it would take nine globes as heavy as Mars to equal the weight of the earth. How wonderful it is that we can tell the mass of a planet although it is millions of miles away! But the power of attraction exerted by Mars on its two little moons (for it has two) gives the secret away. When we know the size of the moons of Mars, and the attractive power that must be exerted by the planet to keep them from wandering away from its guardianship, we can tell how great that power is and how great also is the mass of the planet.

Interesting comparisons can be made between the weight of the same objects on the planet Mars and on the planet earth. *The smaller the mass of the planet, the smaller its attractive power.* A man who here weighs 160 pounds would weigh only sixty pounds on Mars. An athlete who could jump five feet here could jump thirteen feet there. For the matter of that, a Martian elephant might be as graceful as a terrestrial deer.

The mean distance of Mars from the sun is a little more than one and a half times that of the earth (141,500,000 miles), *and its average distance from the earth is* 48,600,000 *miles.* If a railroad track were extended across the space separating us from Mars (when at this distance), a train going at the rate of a mile a minute would take about ninety-two years to make the journey there from our planet.

The year on Mars is equal to 687 days here. That is,

going at the rate of 15 miles a second, the planet requires one year and ten and a half months to complete its annual circuit of the sun. The day lasts about half an hour longer than our day. The seasons probably resemble our own, except in being nearly twice as long. The winter season must be bitterly cold, for Mars, owing to its greater distance from the sun, receives less than one half the amount of light and heat we are accustomed to here. The low density of the atmosphere would lead one to suppose "that the temperature at the equator must be lower than that at the summits of our highest mountains, and far below the freezing point of water."[1]

Climate of Mars

Yet, for some reason so far not discovered, the climate is milder than would seem possible under the circumstances. Perhaps "we see exemplified in Mars the geological period when vines and magnolias flourished in Greenland, and date palms ripened their fruit on the coast of Hampshire."[2]

According to the Milanese astronomer Schiaparelli, the climate of the planet Mars must resemble that of a clear day upon a high mountain — that is, it must be a climate of extremes, with great changes of temperature from day to night and from one season to another. Yet, so far as

[1] C. A. Young, "Lessons in Astronomy," p. 220.
[2] A. M. Clerke, "Astronomy," p. 308.

we can judge, the water is never frozen except very near the poles.

Clouds are rarely observed on Mars, but we have no doubt that they rise and form in the Martian air. During the latter half of October, 1894, an area much larger than Europe remained hidden by mist or clouds. Whether rain was actually falling at that time over Maraldi Sea, the region obscured, we cannot say. Yet we presume that heavy rainfalls are unusual on Mars, and that storms and cyclones such as prevail on earth are unknown in this distant world.

Appearance of Mars

Seen with a powerful telescope, Mars presents the appearance of a miniature earth floating overhead. Ruddy markings indicate islands and continents, while greenish markings outline seas, bays, and marshes. The continents on Mars are somewhat vaguely defined, and are seemingly subject to vast inundations caused by the melting of the polar snows at springtime. Fortunately for us, the oceans on earth keep within certain limits, but on Mars — as M. Faye, the great French scientist, observed in 1892 — "water seems to march about at its ease," flooding from time to time regions as wide as France.

It is possible to follow the progress of the Martian seasons by observing the brilliant white caps that crown the polar regions of the planet. During the long winter

season, these caps (which are probably masses of snow and ice) continue to increase in size, but as springtime advances, the snow rapidly melts away until the merest excuse for a polar snow cap is left, or, as actually happened in 1894, they vanish altogether.

By this means, an immense quantity of water is set free, the polar seas overflow, and as a result the water makes its way over the land as far as the tropics. In 1894, the ice cap was equal in size to a circular mass of ice extending from New York City to the foot of the Rockies, and from the border of Canada to the Gulf of Mexico. Imagine the inundation that would result from the melting of this ice, yet this is a common occurrence on the planet Mars, and happens each year at the return of spring.

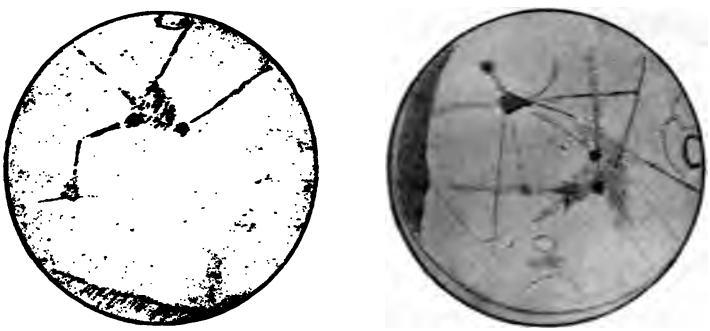
Canals of Mars

Following the melting of the polar snow caps of Mars, "canals" begin to make their appearance as fine dark lines, growing in size until they are about fifty miles wide, when they suddenly change into a double canal. Single canals have been known to "double" themselves in this way within twenty-four hours, the twin canals running side by side like railroad tracks; only, in this case, the tracks are separated by a distance of two or three hundred miles.

There are usually round spots at the junction of the

canals, termed "lakes" by some observers, and "oases" by others. They are about 150 miles in diameter, the largest and most important of all being the "Lake of the Sun," which far exceeds the others in size.

It has been suggested that the canals were constructed for the express purpose of fertilizing the oases, since they are to be found in a region corresponding to the desert



THE CANALS OF MARS AS PHOTOGRAPHED BY PROFESSOR LOWELL.

region on planet earth. Mr. Lowell of the Flagstaff Observatory, Arizona, is of the opinion that what we see is not the canal itself, but vegetation along its banks. Yet this does not account for the "doubling" of the canals, sometimes literally at a day's notice. As the canals widen, the oases darken, and Mr. Lowell suggests that this would seem to indicate that they become covered with vegetation as the season advances. This sounds like a very plausible theory, but, as Professor Young says, "the canals are so

difficult to explain." We can hardly call them rivers, because they are quite straight, yet winding rivers seen from a great height present this peculiarity. Camille Flammarion, the great French astronomer, says that the Rhine, seen from a perpendicular height of eight thousand feet, looks like a green thread drawn in the midst of a ribbon of meadow. The Martian canals, therefore, might be said to correspond to such ribbons.

According to a calculation made by Mr. J. Orr, of the British Astronomical Association, it would require an army of two hundred million men, working for a thousand years, to construct the canal system now outlined on Mars. Nevertheless, owing to the lessened force of gravity on that planet, the men might there attain a strength and stature greater than ours, without being burdened by their own weight. Dealing, as they would have to, with rocks only a little more than a third as heavy as they would be here, their work would be greatly more effective.

Theories Concerning the Martian Canals

Attention was first called to the existence of canals on Mars by Schiaparelli, who saw them in 1877 and in 1879. Their doubling habit was first detected in 1881. These observations were primarily supposed to be illusions, but they were confirmed nine years later by M. Thollon and by M. Perrotin at Nice. Since then many observers, both

in Europe and in the United States, have seen the canals, and most interesting books on the subject have been written by Camille Flammarion and by Mr. Lowell.

Some scientists have been of the opinion that the mysterious doubling of the canals of Mars may be some optical illusion due to defect in the eye of the observer, or to bad focusing of the telescope. Abbé Moreux believed the so-called canals to be in reality cracks in the wrinkled crust of the planet, resembling the cracks on the shriveled surface of the moon. This theory seemed to indicate that Mars was approaching the period of planetary old age, and would eventually become a dead world, like the moon.

In 1902, the canals were gradually becoming an accepted fact, when an interesting experiment, made at the suggestion of Mr. B. W. Lane, of the British Astronomical Association, again caused them to be regarded with suspicion. The experiment was carried out by Mr. J. E. Evans, head master of the Royal Hospital School, Greenwich.

A drawing representing the surface of Mars, but without any lines to indicate canals, was placed by Mr. Evans before a number of boys in the school mentioned. Each boy was asked to make a copy of the drawing. The result was striking. Some drew no canals, but the rest supplied them. It was clear that the variance in the copies depended directly upon the question of the distance of the boys from the drawing. Those near the drawing saw too well and distinctly to imagine lines. Those at a great

distance could perceive only the leading features of the drawing. The boys at a mean distance, by whom the minor details were imperfectly perceived, in many cases rendered them by straight, narrow "canals."[1]

Referring to this experiment, Professor C. A. Young, in his latest edition (1904) of his "Lessons in Astronomy," remarks: "A number of experiments in England and elsewhere . . . have greatly strengthened the doubts as to the reality of the 'canals.' . . . The observers who have mapped the canal system of Mars have doubtless delineated with perfect honesty what they 'saw'; but it now seems very likely that they were victims of an illusion."[2]

Confirmation of Canal Theories. Photographic Discoveries of 1905

Success finally crowned the persistent efforts of Professor Lowell of the Lowell Observatory at Flagstaff, Arizona, to prove by photographic negatives that canals actually exist on Mars.

In July, 1905, Professor Lowell secured a number of excellent negatives of Mars which served to bring us a bit closer to that mysterious, far-away planet than ever before.

"While as yet," commented Professor Downing of

[1] *Knowledge*, November, 1902.

[2] C. A. Young, "Lessons in Astronomy," p. 224.

Columbia University, just after Professor Lowell's discovery, the photographs are hardly more than a Chinese puzzle to the average person, the peculiar markings on them are beyond question the so-called waterways of Mars. Astronomers the earth over recognize the achievement as one of the most important of recent years."

On account of their almost uniform straightness, Professor Lowell still holds to his theory that the canals are artificial in structure.

Is Mars Inhabited?

From all we know of the planet, we can scarcely imagine that Mars would be a comfortable place to live in. The inhabitants must be constantly in fear of the dread results of the springtime inundations, and unless they are equally contented with living on land or on submerged plains, we can scarcely envy the fate of our neighbors in this "Venice of the Sky."

If this planet ever has been, or is at the present time, inhabited, it must be by a race of beings not constituted as we are. As Professor Howe of Denver remarks in his "Descriptive Astronomy," "a man transported from the earth to Mars would, on his arrival there, probably gasp a few times and die." Flammarion suggests that the Martians are winged creatures, but whether birds, bats, or butterflies, he does not attempt to decide. Plans for com-

munication with the supposed inhabitants of Mars, by means of huge signals displayed in deserts, or by gigantic combinations of electric light, have been suggested from time to time, but "are little better than fantasies of a disordered imagination."

According to Professor Young, "while the conditions on Mars are certainly very different from those prevailing on the earth, the difference is less than in the case of any other heavenly body which we can see with our present means of observation; and if life, such as we know life upon the earth, can exist upon any of them, Mars is the place. . . . It is much more probable, however, that the conditions as to temperature and atmosphere differ from our own quite enough to preclude all terrestrial forms of life."

The Moons of Mars

The moons of Mars were discovered by Professor Asaph Hall of the Naval Observatory, Washington, in 1877. The inner one, Phobos, about seven miles in diameter, is at a distance of 5800 miles from the planet's center, and makes one revolution around the planet in a period of seven hours, thirty-nine minutes. Since the day on Mars lasts half an hour longer than a day on earth, Phobos must make three trips around the planet during the course of a day. The inner moon moves so much faster than Mars that, to an inhabitant of the planet, the former would seem

to rise in the west and set in the east, passing through all the phases of new, crescent, and full in a single night.

The outermost moon, Deimos, with a diameter of five or six miles, is at a distance of 14,600 miles from the planet's center, and completes its journey around the planet once in a period of thirty hours eighteen minutes.[1]

The Asteroids or Minor Planets

The asteroids are a number of small planets circling around the sun between Mars and Jupiter. A gap between the two latter planets first suggested the idea that a missing planet, so far escaping detection, must occupy the space. Diligent search was made for it, and the Sicilian astronomer, Piazzi, discovered it on the very first night of the nineteenth century (January 1, 1801). It was named Ceres, after the patron goddess of Sicily. Next year another little planet circling in this space was discovered by a German astronomer, Olbers, and he named it Pallas. A third was found in 1804 by Harding, who called it Juno, and in 1807 Olbers discovered a fourth, to which was given the name Vesta. Since then, "asteroid hunting" by means of photography has revealed the presence of more than five hundred of these asteroids, or "starlike bodies," and new names are constantly being

[1] An amusing account is given of these little worlds, in a book entitled "Poetry of Astronomy," by R. A. Proctor.

added to the list. In fact, the catalogue of these tiny wanderers has been growing with rather inconvenient speed, although a few are of special interest.

Each asteroid, when first observed, is carefully numbered with the year of discovery and labeled with a double letter, as *AB*. Later on, when it has been duly identified as a newcomer, it is given a symbol, that is, a number inclosed in a circle, and a name. For instance, the most interesting of these little bodies is Eros [433], discovered by the astronomer Witt, at the Urania Observatory, Berlin, in 1898. Eros, when at its nearest, comes within 13,000,000 miles of the orbit or path of the earth. In fact, it comes nearer than any other heavenly body except the moon or an occasional comet. By its means we hope to determine more correctly the true distance of the sun from the earth, which distance is still uncertain by perhaps 100,000 miles.

ZONE OF ASTEROIDS BETWEEN JUPITER AND MARS.

Eros is very small, probably less than twenty miles in diameter, and as a rule cannot be seen except in large telescopes. However, there is a possibility of its

becoming nearly bright enough to be seen with the unaided eye, when at its nearest to the earth.

In 1895, Mr. Barnard, now of the Yerkes Observatory, but then at the Lick Observatory, measured the diameters of Ceres, Juno, Pallas, and Vesta. He found that Ceres has the largest diameter, viz. 488 miles; Pallas a diameter of 304 miles; Vesta of 248 miles, and Juno of 118 miles. None of the rest of the asteroids are more than a hundred miles in diameter, while others are probably not more than 12 or 10 miles, mere "mountains broke loose."

It has been estimated that the entire mass of these little worlds cannot exceed one quarter the mass of the earth. If the density of Ceres is the same as that of planet Mars, it would take nearly 6000 such globes to equal the weight of the earth, while the force of gravity on its surface would be about one twenty-second of the force of gravity here. A cannon ball projected from the surface of such a planet would, for example, fly off into space never to return, and would eventually circulate around the sun as a little planet on its own account.

On the smaller planets, only ten miles in diameter, the force of gravity would be even less, so that if there are dwellers on any of these "planetules" (as Miss Agnes M. Clerke, a popular English writer on astronomy, calls them), "should they throw away a stone, it would never come back, but would be from henceforth an independent planet."

A body weighing two hundred pounds on the earth would weigh less than five ounces on the asteroid named Menippe, whose symbol is (188). "A person might there leap to a height of several hundred feet, in which case he would not return in much less than an hour. Of such speculations," as Sir John Herschel, the great English astronomer remarks, "there is no end."

Two theories have been suggested with regard to the origin of the asteroids. Either that they are the fragments of a shattered world, or a world that was "spoiled in the making."

Jupiter, the Prince of Planets

THE KING OF THE GODS. SIGN ♃, "THE BIRD OF JOVE"

"A golden globe, brown-belted — such is Jove,
Four Moons attendant on his wheeling way:
A fifth — so tiny — nestles near the round
Of his vast orb: lately caught
By keen-eyed Barnard on Urania's peak
Through the translucent transatlantic air."

— ARTHUR MEE, F.R.A.S.

Jupiter may well be termed the prince of planets, since it exceeds in bulk, as well as in mass, all the rest of the planets put together. Compared with the earth, Jupiter is about in the proportion of a football to a marble. Thirteen hundred and fifty-five earths would equal the volume of Jupiter, and it would take 316 globes to equal it in weight. *Its diameter is nearly ninety thousand*

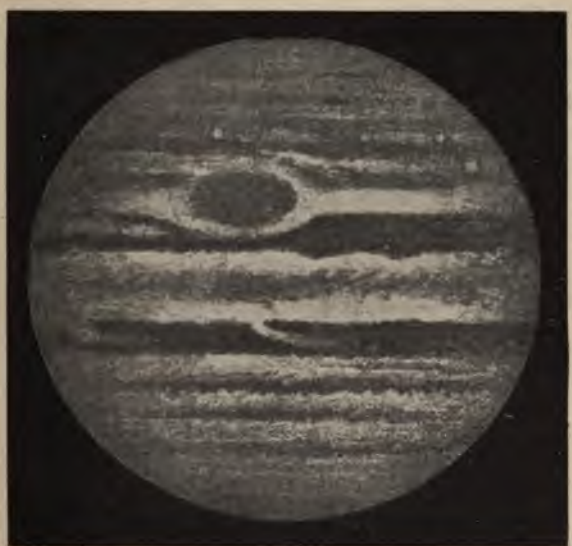
miles, that is a little more than eleven times that of the earth.

The distance of Jupiter from the sun is a little more than five times the distance of the sun from the earth, or 483,000,000 miles. It takes the planet nearly twelve years to go around the sun, although traveling at the rate of eight miles a second. The day on Jupiter is about nine hours and fifty-five minutes, the time during which the planet revolves on its axis.

Jupiter has not yet cooled off, and it is likely that the temperature is considerably above that of boiling water. The planet itself is probably but a semi-liquid mass, its true surface being hidden from view by clouds. Now and then, however, when the great cloud belt which surrounds the torrid regions has been dispersed, a strange fiery hue has been observed, suggesting the idea of a glowing central globe. The suggestion has been made that the planet shines with its own light, but this has not been substantiated by proof, and the theory is therefore not generally accepted.

From the rapid changes that take place in the appearance of the clouds on the planet Jupiter, we judge that they are driven hither and thither at a terrific rate of speed, by cyclonic storms raging at the rate of nearly two hundred miles per hour. Still more remarkable is the fact that these storms have been known to last for seven or eight weeks at a time. Life on such a planet would be out of the question, and for this reason we judge that

Jupiter is as yet in the infancy of its career as a world. When it has settled down from the buoyancy of youth to the sedateness of middle age, — probably millions of years hence, — life may then become possible on its surface, that



THE SURFACE OF JUPITER, AS SEEN WITH THE LICK TELESCOPE, SHOWING THE GREAT RED SPOT.

is, providing the sun is still the dispenser of light and heat to its circling planets.

The color effects noticed in the changing clouds of Jupiter are remarkably lovely, the polar regions being in subdued tones of gray, and the remaining part of the surface showing an infinite variety of detail. The outlines of

the ever varying belts are a constant source of interesting observation to the amateur astronomer.

The Great Red Spot

Red, white, and black spots, appearing in groups and alone, have been observed on the planet Mars. The black spots are seen in the northern hemisphere, the white generally in the southern. Red spots appear occasionally, but they have been eclipsed by a member of their family known as "the great red spot." The latter made its début in the astronomical world in 1878. It was then of a dull hue, but it has since faded away, till it is now "but a ghost of itself." When first seen, it covered a space three thousand miles by seven thousand miles, nearly large enough to inclose three globes the size of the earth.

In 1891, a venturesome black spot drifted in its direction, and finally caught up with it after months of pursuit. Astronomers watched for the result of the meeting with the keenest interest, calculating that the black spot must either go over or under the red spot. It did neither, — the perverse little object, — but simply coasted around it, and "was damaged beyond recognition in the process." By some means it was forced southward and obliged to pass around the "great red spot," as though the latter were an island projecting above a stream. Like the canals of Mars, the red spot still remains an unexplained problem, opinion being

divided as to whether or not it is permanently attached to the planet's surface.

Moons of Jupiter

Jupiter has five moons, four of them large and easily seen with a small telescope, and the fifth extremely small and visible only in the largest instruments.

The names of the four moons (discovered by Galileo in 1610) are Io, Europa, Ganymede, and Callisto. These names are seldom used, however, the moons being referred to by the Roman numerals I, II, III, IV. Io is I, Europa II, Ganymede III, and Callisto IV, in the order of their distance from the planet. The fifth moon, discovered by Professor Barnard in 1892, is known as V, although its path is between Jupiter and Io, and therefore should be I. Too much confusion, however, would result in renumbering the moons, so it is always referred to as V.

The diameter of the fifth moon is only 100 miles. It is 112,500 miles distant from the center of the planet, around which it revolves in a period of nearly twelve hours. It is as faint as a star of the thirteenth magnitude (magnitude referring to brightness not to size, and a star of the first magnitude being the brightest in the sky). It is nestled so close to Jupiter, that it is almost lost in the glare of the planet's light. In fact, the light which Jupiter sheds on the little moon is equal to the combined luster of more than 860 full moons.

Two more little moons have lately been discovered by Professor Charles D. Perrine of the Lick Observatory, California. Early in December of 1904, Professor Perrine was examining some photographs which had been taken of Jupiter. In the region west of the planet he had previously detected the image of an unknown body, and on comparing its position with the photographs he found that it had changed its position from night to night. During the first week of January, he made observations which enabled him to determine whether the unknown body was a new moon in attendance on Jupiter, or merely one of the asteroids. He found that all the positions of the faint object as depicted on a series of photographic plates could be perfectly reconciled as due to the movements of one small body revolving round Jupiter. Details concerning the discovery are few as yet, but the moon is probably at a distance from the planet five or six times greater than that of the outermost of the other five moons. (The outermost moon is 1,169,000 miles from Jupiter.)

While the five moons all move in the same direction around Jupiter, the newcomer, that is, the sixth moon, moves in a reverse direction. It shines with a brightness corresponding to a star of the fourteenth magnitude. Therefore, it is not quite so bright as the fifth moon, which is of the thirteenth magnitude. It is too faint to be seen with the unaided eye, and a telescope of ten or twelve inches is required to make it visible.

Scarcely had the astronomical world recovered from its surprise at the discovery of the sixth moon of Jupiter, when further news came from the Lick Observatory, announcing that Professor Perrine had discovered a seventh moon. The discovery was made on January 6, the day following the announcement with regard to the sixth moon.

While examining some of the photographic plates, Professor Perrine again detected a faint body, which changed its position from night to night. From its motion, the probabilities were in favor of its being another Jovian moon. This has apparently proved to be the case, although some of the German astronomers have suggested that both the sixth and seventh moons lately discovered may prove to be asteroids after all. However, from photographs secured on February 21, Professor Perrine decided definitely that the new body was a moon of Jupiter, but so faint as to be beyond the field of view of any but the most powerful telescopes.

Is it possible that these new moons may be termed newcomers in more senses than one? Did they originally belong to the family of Jupiter, or have they been captured by its immense power of attraction? It is this power which is held responsible for vast gaps and blank spaces where asteroids should be.

Not only has the potent Jupiter caused disturbances amid the tiny planets which form the asteroidal family,

but it has even been known to capture comets. These ethereal visitors from space occasionally drift into the solar system, and usually return whence they came unmolested. Some, however, happening to approach too near the larger planets Jupiter, Saturn, Uranus, and Neptune, have been taken captive, being compelled to become, as it were, a member of one of the "comet families." The comets composing these different families have all been captured by the planet to which they stand related. For instance, Saturn is credited with two comets, Uranus with two, and Neptune with a family of six, while Jupiter's family of comets includes thirty. In 1886, a comet which passed between Jupiter and its innermost moon, that is within about one hundred thousand miles of the planet's surface, was torn into four fragments.

Now if the planet Jupiter has been so successful in capturing comets, why should it not meet with a like success among the asteroids? Naturally suspicion is aroused when two new moons have been so suddenly added to the giant planet's family. How is it that they have so far evaded detection, and that the keen eyes of the astronomers have failed to observe them either by means of the more powerful telescopes or by the careful examination of photographic plates? May not these little bodies now held in bondage by the capturing planet have been formerly members of the family of asteroids? Perhaps they ventured too near the planet and were made captives in consequence.

Discovery of Speed of Light

Every owner of a telescope finds much entertainment in observing the larger moons of Jupiter. One can watch the disappearance of the moons in the shadow of the planet, their reappearance, and also the transits of their shadows as round, black dots moving across the disk of Jupiter. To those who take interests in such observations, "time cannot stale their infinite variety."

By consulting an almanac, we can find out just when to look for these eclipses and can watch them. About two hundred years ago, when astronomers first began to make calculations regarding these eclipses, the little moons gave a great deal of trouble because they did not keep time. Sometimes they were eclipsed a quarter of an hour too soon or too late. Something was decidedly wrong either with the little moons, or with the astronomical calculations.

In 1675, Roemer, a Danish astronomer, came to the rescue, and declared that the little moons were not to blame. The message of light they send to earth requires time for its journey, and the nearer the moons are to the earth, the sooner the message arrives. At certain times Jupiter is nearer to us than at others. For instance, when it is on the same side of the sun as the earth, its distance is 390,000,000 miles; but when the sun is between us and the planet, the latter is at its greatest distance; viz. 580,000,000 miles. The difference between the two dis-

tances is 186,000,000 miles, and causes a delay in the arrival of light from the moons of Jupiter as well as from the planet itself. Jupiter is five times as far from the sun as is our planet. Light takes about eight minutes in coming to us from the sun, and about forty minutes in coming to us from Jupiter. When Jupiter is at its nearest, light reaches us in thirty minutes; when at its greatest distance, the light requires forty-eight minutes for its journey. Knowing the distance of the planet, and the time required by light to cover the distance, Roemer discovered that *light travels at the rate of* 186,330 *miles a second.*[1]

The Ringed Planet, Saturn

THE GOD OF TIME. SIGN ♄, AN ANCIENT SCYTHE

"Slow-moving, leaden, sullen — so described
Yon far-off orb, astrology of old,
But what a scene of wonder doth unfold
Beneath the gaze of science! Circumscribed
By rings and moons resplendent, Saturn sweeps
Majestic through his circuit. Peerless he —
A marvel of design — a mystery
Of beauty poised within those silent deeps!"

— ARTHUR MEE, F.R.A.S.

Saturn was the most remote of all the planets known to the ancients, and in the opinion of the astrologers of

[1] This bold and original suggestion of the great scientist was neglected for more than fifty years, until long after his death, when his views were proved to be correct.

old was considered a planet of "saturnine," or melancholy influence. But to the astronomer it is an object unique among the heavenly bodies, surrounded by a magnificent system of rings and attended by a stately retinue of ten planets, the largest being nearly the size of planet Mars.

The diameter of Saturn is about 75,000 miles, a little more than nine times that of the earth. Its surface is about 84 times that of the earth, and its volume 770 times. Its mass (as determined by means of its satellites) is found to be 95 times that of the earth, so that its mean density equals only one eighth that of the earth, or two thirds that of water. "A mighty globe of water, equal in bulk to Saturn, would actually weigh more. If we could conceive a vast ocean into which a globe equal to Saturn in size and weight were cast, the great globe would not sink like our earth, or like any of the other planets; it would float buoyantly at the surface, with one fourth of its bulk out of the water. We thus learn with high probability that what our telescopes show upon Saturn is not a solid surface, but merely a vast envelope of clouds surrounding a heated interior."[1]

As Professor Young quaintly suggests, "the planet is probably much like Jupiter, though it does not seem to be 'boiling' quite so vigorously." The surface markings of the planet resemble those of Jupiter, a number of belts encircling the planet. The equatorial belt is of a delicate

[1] R. S. Ball, "Story of the Heavens," p. 232.

pinkish tinge, and the pole is adorned with a cap of olive green.[1]

The day on the planet lasts ten hours and fourteen minutes, and the year is equal to about twenty-nine and a half years, the planet traveling at the rate of six miles a second. This is slow compared with the rapid motion of Mercury, Venus, and even that of our own planet earth.

The mean distance of Saturn from the sun is about 886,000,000 miles, or $9\frac{1}{2}$ times the distance of the sun from the earth. A train going 1000 miles a day (nearly 42 miles an hour) would take $254\frac{1}{3}$ years to make the journey to the sun, could railroad tracks be extended across the abyss separating our planet from the sun. To reach Saturn, that same train would require more than nine times as long, or about 2416 years! Simple illustrations such as these probably make us realize more fully the vast extent of Giant Sun's domain.

The Ring System

Planet Saturn is surrounded by a marvelous ring system, its span from tip to tip measuring 173,000 miles. There are three flat rings, generally referred to as *A*, *B*, *C*, the outer one being *A*. Ring *A* is nearly 1200 miles wide, a gap of 2000 miles separating it from Ring *B*, which is

[1] See C. A. Young, "Lessons in Astronomy," p. 240.

After R. A. Proctor.

THE PLANET SATURN AND ITS RING SYSTEM.

about 17,000 miles in width. Ring *C* is transparent, and for that reason is sometimes called the "crêpe veil ring." Through this ring, where it crosses the planet, the outline of Saturn's disk can be clearly seen. It has a width of about 10,000 miles, leaving a clear space of from 8000 to 9000 miles in width between the planet's equator and its inner edge.

There would be room for our planet to circulate between the edge of the *C* ring and the planet, without touching either. Were Ring *C* a smooth roadway, a gigantic ball 7920 miles in diameter, representing the earth, would have space to roll along, and a thousand miles to spare on each side. Along Ring *B*, the broadest of the three rings, there would be ample room for two such globes. The rings are composed of millions of tiny "moonlets," each one moving on its own independent path around the planet. The thickness of the rings is about 100 miles, as proved by the appearance they present when we see them edgewise.

Galileo had a glimpse of the rings in 1610, when he turned his telescope in the direction of Saturn. He saw, as he supposed, a star on each side of Saturn, the three bodies nearly touching each other, and he announced, "I have observed that the most remote planet is triple." But Galileo never solved that problem, and died without having the satisfaction of knowing the "half discovery" he *had made*.

The Moons of Saturn

Saturn has a family of ten moons, the tenth being a very newcomer. It was discovered in April, 1905, by Professor W. H. Pickering of Harvard University, who also discovered the ninth moon of Saturn in 1899. The period of the new satellite is twenty-one days, so that its distance from Saturn is a little less than that of the smallest moon of Jupiter, — Hyperion, discovered by Professor Bond at the Harvard College Observatory in 1848. The motion in its orbit is direct.

The names of the other moons, in the order of their discovery, are Iapetus, Hyperion, Titan, Rhea, Dione, Tethys, Enceladus, Mimas, and Phœbe. The range of the system is enormous. Iapetus has a distance of 2,225,000 miles, with a period of 79 days. The largest of all, Titan, is 3000 or 4000 miles in diameter. Its distance is about 770,000 miles, and it circles around the planet in a little less than 16 days.

The Planet Uranus

"HEAVEN," OR URANUS, THE MOST ANCIENT OF THE GODS. SIGN ♅, H, THE INITIAL LETTER OF HERSCHEL, WITH A PLANET SUSPENDED FROM THE CROSSBAR

Beyond Saturn is the planet Uranus, which was discovered March 13, 1781, by Sir William Herschel, the

English astronomer. One evening when he was observing the star depths with one of his large telescopes, he noticed a star that did not present the usual starlike point of light, but a round disk more like a planet.

Sir William Herschel.

After watching it carefully for several months, he came to the conclusion that it was a comet, but later decided that it was a planet. As this was the first planet that had ever been "discovered," the news caused great excitement in the astronomical world.

After ascertaining the path of the new planet, Herschel was enabled to trace its course backward, and to find where it had been at various times before its discovery. He found that the planet had already been observed no less than nineteen times, and an eminent French astronomer, Lemonnier, had actually seen it twelve times. Lemonnier was not what might be termed an orderly worker; his astronomical papers were usually scattered in a chaotic state about his study. One writer says that he had "seen one of Lemonnier's observations of this very star written on a paper bag which had contained hair powder." So narrowly then had the planet escaped recognition, until its discovery rewarded Sir William Herschel — the most laborious of all astronomers.

The new planet was named Uranus, although for a time it was referred to as Herschel's planet. It appears as bright as a star of the sixth magnitude, and is easily visible to those who have good eyesight. In the telescope, it shows a greenish disk, and there are faint traces of belts resembling the belts of Jupiter.

The mean distance of Uranus from the sun is about 19 times that of the earth, or about 1,800,000,000 miles. Its year is equal to 84 years on our planet, and it moves around the sun at the leisurely pace of $4\frac{1}{3}$ miles per second. Its diameter is about 32,000 miles, its bulk 66 times that of the earth, and its mass about 14 times that of the earth.

Moons of Uranus

The planet has four moons, named Ariel, Umbriel, Titania, and Oberon. The two brightest, Oberon and Titania, were discovered by Sir William Herschel a few years after he had discovered the planet itself. Ariel and Umbriel were discovered by Lassell in 1851. They are among the smallest bodies in the solar system and the most difficult to see. Like the new sixth moon of Jupiter, and Phœbe, the ninth moon of Saturn, the four Uranian moons revolve backward.

Planet Neptune

In the year 1846, Uranus was obliged to resign its position as sentinel of the solar system. A new planet, which was called Neptune, was discovered traveling far beyond the orbit of Uranus. Its discovery was one of the greatest achievements of mathematical science, and a few words may explain how the planet was found.

The sun, as already mentioned, controls the movements of its large family of planets by means of its attractive power, and succeeds in keeping them all in their paths. The planets also exert an attractive influence over each other, and as they are swayed to and fro, a constant struggle seems to be taking place in the solar family. At one time Jupiter is disturbing the asteroids, or Saturn is drawing Uranus from its path, and these planetary disturbances make the planets swerve slightly.

After the discovery of Uranus, it was found that it followed the example set by the other planets, and was not only swayed by the attraction of Jupiter and Saturn, but at the same time seemed to be drawn in the other direction, away from Saturn. The difference between the place where the planet should have been and where it was excited universal interest. By 1845 the planet had gone so far astray from its path that the amount, though comparatively minute, was quite noticeable.

Two astronomers, Leverrier of Paris and Adams of England, made calculations proving that there must be a planet beyond Uranus causing it to swing beyond its assigned path. Both astronomers solved the problem, arriving at the same result by different methods.

Leverrier (1811–1877) wrote to Galle, an astronomer at Berlin, directing him to turn his telescope to a point on the ecliptic in the constellation of Aquarius. Leverrier assured him that there he would find within a degree of that place a new planet, with a round disk, looking like a star of about the ninth magnitude. The planet was discovered at Berlin, on the night of September 23, 1846, within half an hour after the astronomers began looking for it, and within a short distance of the precise point indicated by Leverrier.

The new planet was found to be at a distance from the sun a little less than 2,800,000,000 miles, or about 30 times the distance of the sun from the earth. It takes

164 years in making its journey around the sun, moving at the rate of $3\frac{1}{3}$ miles per second.

The diameter of Neptune is about 30,000 miles, which makes its volume about 60 times that of the earth. Its mass, determined by its moon (for it has only one), is about 18 times that of the earth. Neptune's moon was discovered by Lassell, within a month after the discovery of the planet itself. Like the moons of Uranus, it revolves backward.

When seen through a telescope, the planet presents the appearance of a small star between the eighth and the ninth magnitude. It cannot be seen with the unaided eye, but a good opera glass brings it into view. There are no visible markings upon its surface.

If the planet were an inhabited world at any time, it would prove to be a gloomy abode, since it receives but one nine-hundredth of the light and heat we are accustomed to here. "At the distance of Neptune, the sun gives a light nearly equal to 700 full moons — about 80 times the light of a standard candle at one meter's distance — and is abundant for all seeing purposes. In fact, as seen from Neptune, the sun would look very like a 1200 candle-power electric arc at a distance of only 12 or 13 feet.[1]

[1] C. A. Young, "Manual of Astronomy," p. 407.

CHAPTER VI

COMETS, METEORS, AND SHOOTING STARS

"Whence art thou, say, thou pale-winged messenger?
And whither goest? What thy history?
And what thy future? Tell a waiting world
Ere visiting again yon silent deeps."

—ARTHUR MEE, F.R.A.S.

THE word "comet" is derived from a Greek word which means a "hairy star." Comets are mysterious visitants from the star depths, coming we know not whence, and going we know not whither. A comet when first seen resembles a round, misty cloud with a bright, starlike center. A long, fan-shaped train of hazy light is developed as the comet approaches the neighborhood of the sun, and as it draws nearer and nearer to the sun, the train increases in length, sometimes reaching to a distance of many millions of miles. After the comet whirls around the sun, these glories soon fade until finally the comet itself vanishes from view. While the trains of some comets are but faint wisps of light, others are magnificent objects.

"Sometimes comets are as bright as Venus and visible by day, with a head as large as the moon, and having a

train which extends from the horizon to the zenith,[1] and is really long enough to reach from the earth to the sun." [2]

Some Remarkable Comets

The great comet of 1811 had a head 112,000 miles in diameter, and its nucleus, or central starlike point,

Changes of a Comet When First Seen.

was 400 miles in diameter. Its tail stretched out to a distance of 112,000,000 miles. The comet was of sufficient length to reach from the earth to the sun and 19,000,000 miles beyond.

[1] *Zenith* is the point exactly overhead.
[2] C. A. Young, "Lessons in Astronomy," p. 252.

One of the finest comets ever seen was Donati's comet of 1858, Donati[1] being the name of the discoverer. The head of the comet was 250,000 miles in diameter, more than three times the diameter of the earth. When the comet first became visible to the unaided eye, it had a very small train, but as it gradually drew nearer to the sun, the train spread out for millions of miles,

How a Comet's Train Changes in Appearance.

assuming magnificent proportions. Finally the comet disappeared, but it will return again after a period of two thousand years.

Another comet, whose return may be expected in 1911 or thereabouts, is known as Halley's comet. This comet

[1] Donati, an Italian astronomer, at Florence (1827–1873).

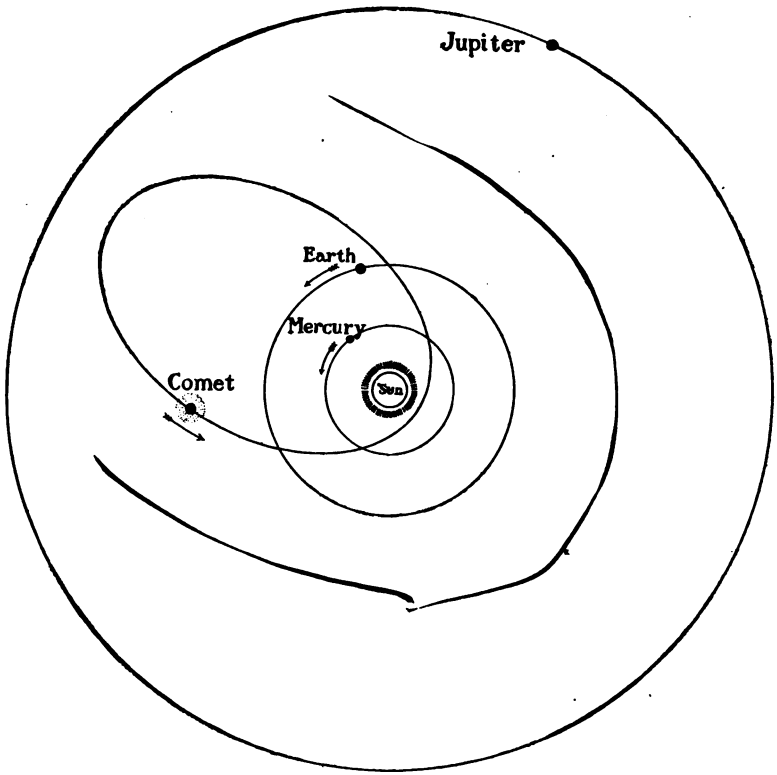
was named, as is usually the case, after its discoverer, Halley,[1] who saw it in 1681. From certain observations made with regard to the path of this comet, Halley announced that it would return to the neighborhood of the sun after a period of about seventy-six years. The prediction came true, and the comet was again observed in 1759 and 1835 and, as already stated, is expected again about 1911. In fact, the German Astronomical Society has offered a prize of 1000 marks for the most exact calculation of the next appearance of Halley's comet. The paper may be written in English and need not be presented until the end of the year 1908.[2]

Another comet which is a regular and frequent visitor to our solar system is named after its discoverer, the German astronomer, J. F. Encke (1791–1865). It was first seen in 1818, and its period is a little more than three years; but for some reason the period is growing shorter, and in 1902 it was about fifty-four hours less than in 1819. The mean distance of the comet when at its nearest to the sun is now nearly a quarter of a million of miles less than in the year of its discovery. At first it was thought that the delay was caused by the comet being obliged to force its way through a thin, diffused atmosphere surrounding the sun, but as other comets have not been delayed in this way, the theory was not accepted.

[1] E. Halley (1656–1722), Second Astronomer Royal.

[2] "Science," N. S., Vol. XXI, No. 256.

Encke's delay may possibly be due to obstacles that it meets on its way during the course of its journey around



THE PATH OF ENCKE'S COMET.

the sun, such as a cloud of meteors, or disturbances caused by some unknown body in the region of the asteroids. The orbits of these tiny planets interlace in a wonderfully

complex fashion, ranging widely above and below the general level of the paths of the larger planets. In this way, these minute bodies are a source of danger to unwary comets, and may be the cause of Encke's lack of promptitude.

A similar reason, probably, may account for the loss of Biela's comet, which was discovered in 1826, by an

BIELA'S COMET IN 1846, BEFORE ITS DIVISION INTO TWO.

Austrian officer named Biela. It was a small comet with a period of about six years, and its path came within a very few thousand miles of the earth's path. In fact, the approach was often so close that had the comet and the

earth arrived at the nearest point at the same time, there would have been a collision. At the return of the comet in 1832, it was announced that it would cross the path of the earth. This caused a "comet scare" in southern France.

The ignorant anticipated dire results, should the comet collide with the earth, and Arago, of the French Academy of Science, did his best to allay their fears. It appears that the writer of the alarming news failed to state one very important item; viz. that although the outer portions of the head of the comet (which sometimes extend to a distance of thousands of miles, usually from forty to one hundred thousand miles) would probably envelop a certain *point* of the earth's path, yet the earth would not reach that point till a month later. In fact, at the critical moment, the comet and the earth were separated by the comparatively safe distance of fifteen million miles! The dread of a collision, therefore, was just as uncalled for as would be the fears of a passenger on an express train, who should be in terror of his life because another express train would cross the line at a certain point an hour before his own train reached that point.

It is related that when some kind-hearted astronomer, anxious to quiet popular apprehension, carefully explained that the orbit and not the earth would be crossed by the comet, some were in dread "lest the earth's orbit would suffer," supposing the orbit to be something material — a

circle of metal, for instance. "Had a meeting taken place," as Sir John Herschel wrote, in 1866, "from what we know of comets, it is probable that no harm would have happened, and that nobody would have been any the wiser."

Soon after the return of Biela's comet, in 1846, it performed the remarkable feat of splitting in two. The twin

BIELA'S COMET AFTER ITS DIVISION INTO "TWIN COMETS."

comets sailed along side by side, separated by an almost unchanging distance of about 165,000 miles. At their next return, in August, 1852, the twins had drifted still farther apart, the distance being now about 1,500,000

miles. On November 27, 1872, just as the earth was crossing the track of the comet, but some millions of miles behind where the comet ought to be, there occurred a wonderful display of meteors. Similar displays took place in 1885, when the earth once more crossed the path of the comet, and again in 1892 and 1898, — the last very feeble. "It is not certain whether the meteor swarms were the remains of the comet itself, or whether they were other small bodies merely following in its path. But the comet cannot be found, and if it still exists and occupies the place it ought to, it must have somehow lost the power of shining."[1]

The comet discovered in 1893 by Lewis Swift of California, and named for him, was remarkable "on account of the marvelous changes in its tail. On April 4 it was 20° long, straight and slender; in the telescope it was seen to consist of two branches, between which scarcely any cometary matter was visible. The next morning a new tail had formed between the other two, and each tail was composed of several lying close together. At least a dozen could be counted. After the lapse of another day, one of the original three tails had vanished, and the other two were blended.

"Then one of these grew bright, and the other faded away; the bright one had a sharp bend in it, as if turned aside by some obstacle. Near the point of deflection were

[1] C. A. Young, "Lessons in Astronomy," p. 274.

SWIFT'S COMET OF 1892, PHOTOGRAPHED BY BARNARD.

two dark spots in the brightest part of the tail. Finally the tail split up into six branches. All these changes and some others took place in five days." [1]

[1] Herbert A. Howe's "Elements of Descriptive Astronomy," p. 204.

The Brooks's comet of 1893 was discovered on October 17 of that year by William R. Brooks of Geneva, New York. The tail of this comet also underwent wonderful changes, interestingly described by Dr. E. E. Barnard as follows:—

"It presented the comet's tail as no comet's tail was ever seen before. The graceful symmetry was destroyed;

Brooks's Comet, October 21, 1893, Photographed by Barnard.

the tail was shattered. It was bent, distorted, and deflected, while the larger part of it was broken up into knots and masses of nebulosity, the whole appearance giving the idea of a torch flickering and streaming irregularly in the wind. The short northern tail was swept entirely away, and the comet itself was much brighter.

"The very appearance at once suggested an explanation, which is probably the true one. If the comet's tail, in its flight through space, had suddenly encountered a resisting medium which had passed through the tail near the middle, we should have precisely the appearance presented by the comet. It is not necessary that the medium should be a solid body; if it possessed only the feeblest of ethereal lightness, it would deflect, distort, and shatter the tail. What makes this explanation all the more probable is that the disturbance was produced from the side of the tail that was advancing through space." [1]

Star Showers

There seems to be a connection between the meteoric fragments seen at the time Biela's comet is due, and a swarm of meteors which radiate from the star Gamma in the constellation of Andromeda. Hence their name "Andromedes," these showers occurring about once in thirteen years.

Another remarkable shower is that known as the Leonids, since the meteors radiate from the sickle-shaped group of stars in the constellation Leo. These showers are due every thirty-three years, about the 13th of November. In 1833, the display was marvelous, the meteors, we are told, falling as thickly as snow-flakes.

[1] *Popular Astronomy*, December, 1893.

One of the planters of South Carolina gave a most impressive account of the consternation caused among the negroes on this occasion: "I was suddenly awakened by the most distressing cries that ever fell on my ears. Shrieks of horror and cries for mercy I could hear from most of the negroes of the three plantations, amounting in all to about six or eight hundred. While earnestly listening for the cause, I heard a faint voice near the door calling my name. I arose, and taking my sword, stood at the door.

"At this moment I heard the same voice still beseeching me to rise, assuring me that the world was on fire. I then opened the door, and it is difficult to say which excited me the most, the awfulness of the scene or the distressed cries of the negroes. Upward of a hundred lay prostrate on the ground, some speechless and some giving utterance to the bitterest cries. With hands upraised, they implored God to save the world and them. The scene was truly awful, for never did rain fall much thicker than the meteors fell toward the earth — east, west, north, and south, it was the same."

In 1866, Europe seemed to be the main target of the fiery darts, and dense crowds of meteors filled the sky.[1] Elaborate preparations were made for an unexpected display of the Leonids in 1899 and again in 1900, but comparatively few were seen.

[1] In "Starry Realms," Sir R. S. Ball gives a graphic account of his experience on that occasion.

Meteors

Sometimes the meteors fall to earth, — they are then termed *meteorites*. The total number which have fallen and have been placed in museums since 1800 is about 275. Ten of these are masses of iron, but by far the greater number are stones. The surface of a meteorite is usually uneven, and is covered with a thin crust.

Meteors first appear at a height of about 80 or 100 miles and disappear at a height of about 5 to 10 miles. The length of the path may be anywhere between 50 and 500 miles, though in some cases it has been known to be greater. These bodies enter the air which surrounds the earth with a speed of about 10 to 40 miles a second, but they travel far more slowly before they finally disappear.

As to what a meteor is, various ideas have been advanced. Some think that they may have been thrown out from the now extinct volcanoes of the moon, with a velocity sufficient to make them planets for the time being. Thus they traveled on independent paths, until they encountered the earth and its attraction drew them to its surface. Others say that the meteors were ejected from the giant planets, or even from the earth itself in the days when it was young. But they cannot be the *immediate* product of eruptions from volcanoes, either terrestrial or lunar.

Shooting Stars

The tiniest member of Giant Sun's family is a shooting star. So minute is it that it could easily be held in the hand. It first appears at a height of about 74 miles and disappears at an elevation of about 50 miles, after pursuing its way along a path 40 or 50 miles long, with a speed of 10 to 50 miles a second — usually about 25 miles a second. As shooting stars plunge into the atmosphere surrounding the earth, they rub against every little particle they meet on the way. This causes friction, and for a moment we see it as a bright star in the sky; the next, it vanishes, fading into mist or dissolving into star dust.

Giant Sun's Endless Journey

The sun is drifting onward through space at the rate of about eleven miles a second, yet in a million years it may not have shifted from its present place in the sky by more than the width of the full moon. "The more one considers this celestial journey, the stranger seem the adventures of the sun and its attendant planets in their journey through space. The journey is an actual one, for a railroad does not more surely whirl us to our destination, than by this great solar migration we are swept through the abyss of the heavens toward the constellation Hercules, only in one case the rate of speed is more accurately

ascertained than in the other. The wildest imaginings of the Eastern fortune tellers, with their magic horses and enchanted carpets, seem spiritless in comparison with what science has to tell us of the wonderful journey, in which we are all unconsciously engaged. A celestial eye that closed in the slumber of the gods, if suddenly opened now, would look in vain for the fields and woods of Paradise. They have disappeared, together with their inhabitants, and the blazing orb that shone upon Eden would likewise have disappeared. The sleeper awakened would find himself plunged in eternal night, and the awful cold of sunless space. During his sleep the whole system would have passed on, leaving him millions of miles behind, like an abandoned traveler in a desert.

"Who would not wish to see with an all-seeing eye the caravan of worlds on its way? Always gathering new materials from the realms of space, adding comets and meteor swarms to its dominion, the sun sweeps on and the obedient planets follow in widely circling orbits; but whither we are going and how it is all to end, even the astronomers cannot tell."

"Hail! O gracious sun.
Giant! thy bulk o'erwhelms the wondering mind,
Eight hundred thousand leagues thy girth to bind
Would scarce suffice. Thy power extends afar
To where the bounds of distant Neptune are;
And comets numberless thy sway confess,
Nor 'gainst thy law a finger's breadth transgress.

Nor only great art thou, and ruling all
Beside thee great; but He who marks the fall
Of tiniest sparrow, bids thee bow thy pride,
And tend the humblest flower on pathway side,
And warm it into life to bud and shine,
A star of earth. Nor less thy power divine
In these small acts, than ruling all the hosts
Of worlds resplendent that our system boasts."

—ARTHUR MEE, F.R.A.S.